U.S. Fish & Wildlife Service

HABITAT MANAGEMENT PLAN FOR

MANDALAY
NATIONAL WILDLIFE REFUGE

Terrebonne Parish, Louisiana

Southeast Region

Mandalay National Wildlife Refuge

Habitat Management Plan

U.S. Department of the Interior
Fish and Wildlife Service
Southeast Region

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Summary

Mandalay National Wildlife Refuge (NWR) is one of eight refuges in the Southeast Louisiana National Wildlife Refuge Complex (Complex), which administers over 160,000 acres of habitat from marshes to upland forests across the southeastern quarter of the state. Together these refuges provide high-quality habitat for waterfowl, water birds, breeding and migratory land birds, and threatened and endangered species, and support a range of ecosystems representing the natural diversity of the central Gulf coast. This Habitat Management Plan (HMP) provides goals, objectives, and detailed strategies for managing Mandalay NWR's 4,416 acres of marshes and wetland forests for the benefit of its resources of concern. It is a step-down plan of the Comprehensive Conservation Plan (CCP) for Mandalay NWR (U.S. Fish and Wildlife Service 2009).

Resources of concern were selected based on statutory requirements and reflect the highest priorities for refuge management, as outlined in the CCP. Resources of concern for Mandalay NWR are:

- Waterfowl
- Marsh Birds
- Colonial Nesting Wading Birds
- Raptors

Objectives must reflect refuge purposes with respect to the resources of concern. The following habitat management objectives have been selected to support and add detail to goals and objectives in the CCP:

Objective 1.1: Each year through the end of the planning period for this HMP, restore and maintain 3,700 acres of freshwater marsh and shallow open water habitats as follows:

- Marsh is approximately 50 percent emergent vegetation and 50 percent open water, with open-water portions dominated by native floating-leaved and/or submersed aquatic vegetation;
- Open-water ponds and lakes are substantially free of floating mats of exotic invasive weeds (i.e., exotic floating mats cover less than 5 percent of the surface of Hanson Unit 1 and Lake Hatch Unit 2 at all times);
- Marsh vegetation loss from nutria and hogs is negligible;
- Loss of marsh habitat from erosion is halted by 2020.

Objective 1.2: Working with partners, every 5 years over the planning period covered by this HMP, as funding is available, restore up to 100 acres of rooted emergent or flotant marsh on Mandalay NWR by planting, deposition of dedicated or beneficial dredge material, construction of organic fences (Christmas tree cradles) and/or installation of hardened structures along shorelines.

Objective 2.1: As funding becomes available, during the planning period covered by this HMP, protect, manage, and restore 250 acres of bottomland hardwood forest and cypress-tupelo swamp (including hardwoods on approximately 103 acres of spoil banks along dredged canals) on Mandalay NWR so that:

- Land loss along the Gulf Intercoastal Waterway (GIWW) is stopped and reversed;
- Exotic invasive woody plants make up less than 5 percent of the canopy cover;

- Suitable, well-spaced cavity nesting sites (natural or artificial) exist in sufficient numbers so that cavity availability does not limit breeding wood ducks and black-bellied whistling-ducks;
- Suitable emergent tree crowns exist to provide nesting sites for bald eagles and ospreys;
- Enough suitable rookery sites exist so that availability does not limit breeding by colonial nesting wading birds;
- Exotic animals, particularly feral hogs, neither impact native wildlife nor degrade habitat to a significant degree.

The following strategies have been devised to best achieve the selected goals and objectives:

- To meet Habitat Management Objective 1.1, integrated pest management principles will be applied to controlling salvinia, water hyacinth, Cuban bulrush, and Chinese tallow. Releases of *Cyrtobagous salviniae* will continue until the insect is well-established on the refuge. Salvinia infestations will be periodically monitored to determine efficacy of this control method and to ascertain whether the insect is successfully established. Approved herbicides will be used as needed to control water hyacinth and Cuban bulrush where they form floating mats and degrade marsh and shallow open water habitat. All herbicides will be approved through the Pesticide Use Proposal process and will follow Integrated Pest Management Policy (569 FW 1). An up-to-date list of approved herbicides is kept on file at the Complex office.
- To meet Habitat Management Objectives 1.1 and 1.2, the following strategies will be used to control nutria and feral hog populations:
    - Conduct yearly evaluations of nutria and feral hog populations on refuge lands, using established monitoring protocols.
    - Continue to partner with area trappers to reduce nutria and feral hog populations.
    - Participate in the State of Louisiana Nutria Control program by actively promoting the program and seeking assistance from area trappers to reduce nutria populations on refuge lands consistent with the state's Nuisance Animal Control Plan.
    - Focused nutria control (i.e., contract trapping, shooting) will be practiced as needed in the event that flotant marsh creation is implemented on an operational basis, as recommended by (Sasser et al. 2010).
- To meet Habitat Management Objectives 1.1 and 1.2, the following strategy has been selected to control erosion along the GIWW:
    - Refuge will seek funding to implement successful bank stabilization practices at operational scale along the GIWW. Where appropriate, marsh restoration strategies will be coupled with bank stabilization.
- To meet Habitat Management Objective 1.2, the following strategies have been selected to restore marsh vegetation on Mandalay NWR:
    - Refuge will seek funding to implement beneficial or dedicated dredge deposition projects along the GIWW, focusing on open-water areas behind bank stabilization projects and open ponds where there is a risk of breakthrough to the GIWW.
    - Refuge will work with partners and volunteers to plant appropriate emergent marsh species in beneficial dredge spoil deposition sites, areas where nutria have denuded marsh vegetation, and areas behind bank stabilization projects where sediment has accumulated and natural revegetation is inadequate.
    - In the event that significant areas of floating marsh are lost to storm damage, nutria, or other causes, the refuge may seek funding to implement operational flotant marsh restoration as described by (Sasser et al. 2010).

The following strategies will be used to manage forested wetland habitat to achieve Habitat Management Objective 2.1:

- Chinese tallow will be controlled on bottomland hardwood sites in the Ridge Canal unit by application of Garlon 4 or equivalent as a basal spray in diesel, or by other herbicide treatment as approved. The unit will be assessed at least every 3 years, and treatment will be prioritized by density and age of tallow trees (i.e., seed-bearing populations will receive higher priority). Infestations which are interfering with natural regeneration in blowdowns (areas of windthrown timber) and other disturbed areas will also receive high priority for treatment. Tallow infestations on spoil banks will be treated as funding and resources are available, but are a lower priority than those in natural habitats. All herbicides will be approved through the Pesticide Use Proposal process and will follow Integrated Pest Management Policy (569 FW 1). An up-to-date list of approved herbicides is kept on file at the Complex office.
- Management will evaluate the need for an artificial nest cavity program for waterfowl. Low levels of use in past years, coupled with a healthy population of wood ducks on the refuge, indicate that natural cavities are not limiting wood duck breeding. Periodic monitoring of wood ducks will be used to support decisions on increasing, decreasing, activating, or deactivating the program in the future. Funding constraints will be considered when deciding where and how many boxes will be placed.
- In the Ridge Canal unit, areas of blowdown and other disturbance will be allowed to naturally regenerate. As funding and resources are available, the refuge will supplement natural regeneration with seedlings of hard mast-producing species (water oak, Nuttall oak, water hickory) when these species are lacking due to absence of seed sources on otherwise compatible sites. Management will also consider reforesting areas of spoil banks or other suitable areas that have been cleared for oil and gas operations or other uses and need restoration.
- Currently, human disturbance of the eagle nest has not been a problem since the area around the nest is relatively inaccessible. The staff will monitor the situation for any changes, and will implement appropriate buffer zones if necessary.

Recommended Citation

U. S. Fish and Wildlife Service. 2012. Mandalay National Wildlife Refuge Habitat Management Plan. U.S. Fish and Wildlife Service. Atlanta, GA 88 pp.

I. Introduction

Since the establishment of Pelican Island National Wildlife Refuge in 1903, the Fish and Wildlife Service (Service) and its antecedents have managed habitat for fish, wildlife, and plants for the benefit of the American people. Over the past 110 years, the National Wildlife Refuge System (Refuge System) has grown from that small beginning to a nationwide network of lands and waters totaling over 150 million acres on which wildlife comes first. Now in the second decade of the Twenty-first Century, the role of national wildlife refuges is becoming increasingly important. Threats on an unprecedented scale–global climate change, exotic invasive species, and unsustainable land uses–are causing irreversible changes to the natural systems on which we all depend. Properly managed conservation lands, scaled to the level of the threats they face, not only continue to serve their traditional purposes, but are also becoming increasingly essential to ensure the survival of natural systems and species, including our own. To meet these new challenges, managers will need to incorporate change and flexibility into land management plans. Adaptive management, "the rigorous application of management, research, and monitoring to gain information and experience necessary to assess and modify management activities" (602 FW 1), has been incorporated into Service policy and will increase flexibility and effectiveness of management on Service lands.

Planning is recognized as an integral part of Strategic Habitat Conservation, which the Service has adopted as the framework for accomplishing its mission. Refuges are the primary vehicle through which the Service's new strategic emphasis is put into practice. This HMP serves as the final link from the strategic vision set forth in the Service's publication, "Conserving the Future" (U.S. Fish and Wildlife Service 2011), and telegraphed down through the refuge CCP. Actions prescribed herein make the vision a reality.

SCOPE AND RATIONALE

VISION

The CCP laid out a vision for the refuge:
Mandalay National Wildlife Refuge will be managed as a productive freshwater marsh that provides essential wintering habitat for migratory birds along the Louisiana coast. The highest priority for the refuge will be to maintain prime waterfowl, shorebird, and wading bird habitat. The refuge will play a critical role in coastal restoration and erosion control efforts. This will be accomplished through agency coordination, to ensure quality coastal wetland habitat over the next 15 years. Mandalay NWR will provide the best possible habitat for mammalian, fish, amphibian, reptilian, and other avian species. Visitors to the refuge will enjoy a quality outdoor experience centered on the traditional uses of hunting and fishing, while cultivating a conservation ethic that promotes stewardship of important wildlife habitat.

SCOPE

This HMP is a step-down plan to the 2009 CCP. Habitat management plans describe refuge resources, identify those resources which are of particular management concern, lay out goals and objectives related to the resources of concern, and describe strategies designed to achieve the stated objectives. They focus on habitat management actions taken at the local scale which impact resources both locally and across the landscape. They are based on sound science and incorporate adaptive management principles as part of a strategic habitat conservation approach. The goals and objectives contained in this

HMP support the refuge vision and the wildlife and habitat management goals and objectives in the CCP, which in turn reflect the information and recommendations in the Biological Review (U.S. Fish and Wildlife Service 2006), internal scoping within the Service, and information and recommendations gathered from the public and governmental partners during public scoping for the CCP.

RATIONALE

Our goals for this HMP are:

- Provide for long-term continuity of management direction;
- Describe desired future habitat conditions on the refuge;
- Document refuge management goals, objectives, strategies, and their rationale for interested members of the public;
- Ensure and facilitate compliance of refuge management actions with relevant policies and legal requirements;
- Document how the refuge will support larger scale conservation planning efforts by the Service and others;
- Create a reference and basis for prioritization of future operation, maintenance, and capital expense requests.

LEGAL MANDATES

The statutory authority for habitat management planning on refuges is derived from the National Wildlife Refuge System Administration Act of 1966 (Administration Act), as amended by the National Wildlife Refuge System Improvement Act of 1997 (Improvement Act), 16 U.S.C. 668dd - 668ee. Section 4(a)(3) of the Improvement Act states: "With respect to the System, it is the policy of the United States that each refuge shall be managed to fulfill the mission of the System, as well as the specific purposes for which that refuge was established" and Section 4(a)(4) states: "In administering the System, the Secretary shall monitor the status and trends of fish, wildlife, and plants in each refuge." The Improvement Act provides the Service the authority to establish policies, regulations, and guidelines governing habitat management planning within the System. The Improvement Act prepared the way for a renewed vision for the future of the Refuge System where:

- Wildlife comes first
- Refuges are anchors for biodiversity and ecosystem-level conservation
- Lands and waters of the Refuge System are biologically healthy
- Refuges are national and international leaders in habitat management and wildlife conservation

Actions prescribed in HMPs comply with all applicable laws, regulations, and policies governing the management of Refuge System. The lifespan of an HMP is 15 years and parallels that of refuge CCPs. HMPs are reviewed every 5 years by a peer review process, as appropriate, in the HMP revision process or when initiating CCPs.

REFUGE PURPOSES

The purposes of a national wildlife refuge, as established by Congress or the Executive Branch, are the standards by which all actions on the refuge are measured. Habitat management, public use, and all other programs are required to fulfill the established purposes of the refuge. Mandalay NWR was established in 1996 for the following purposes:

"for use as an inviolate sanctuary, or for any other management purpose, for migratory birds" 16 U.S.C. 715d (Migratory Bird Conservation Act).

"to conserve (A) fish or wildlife which are listed as endangered species or threatened species or (B) plants" 16 U.S.C. 1534 (Endangered Species Act of 1973) (U.S. Fish and Wildlife Service 2009). The Improvement Act provides guidance for the mission of the Refuge System and priority wildlife-dependent public uses. The Improvement Act states that each refuge will:

- Fulfill the mission of the Refuge System;
- Fulfill the individual purposes of each refuge;
- Consider the needs of wildlife first;
- Fulfill requirements of comprehensive conservation plans that are prepared for each unit of the Refuge System;
- Maintain the biological integrity, diversity, and environmental health of the Refuge System; and
- Recognize that wildlife-dependent recreation activities, including hunting, fishing, wildlife observation, wildlife photography, and environmental education and interpretation are legitimate and priority public uses; and allow refuge managers authority to determine compatible public uses.

RELATIONSHIP TO OTHER PLANS

REFUGE PLANS

Comprehensive Conservation Plan: The Mandalay NWR CCP (U.S. Fish and Wildlife Service 2009) gives a broad overview of management for the refuge, and provides goals, objectives, and strategies which serve as guidelines for management over a 15-year period. This HMP provides specific prescriptions to implement the CCP goals and objectives which relate to habitat management.

REGIONAL AND NATIONAL BIRD CONSERVATION PLANS

Mandalay NWR provides important habitat for resident and migrating birds throughout the year. A number of regional and national-scale plans address various aspects of bird conservation relevant to Mandalay NWR. These are discussed below.

North American Bird Conservation Initiative

The North American Bird Conservation Initiative (NABCI) (North American Bird Conservation Initiative n.d.) is a group of agencies, private organizations, and others which work together to promote conservation of birds and their habitats across North America. The group identifies and coordinates actions which can be accomplished by its members toward that end, including land conservation, monitoring, landscape-scale conservation design, and support within government agencies for bird conservation. Four taxonomically delineated bird conservation planning initiatives fall under the auspices of NABCI: the North American Waterfowl Management Plan, the Partners in Flight North

American Landbird Conservation Plan, the United States Shorebird Conservation Plan, and Waterbird Conservation for the Americas: the North American Colonial Waterbird Conservation Plan. Each of these initiatives in turn has regional planning efforts which focus in more detail on individual Bird Conservation Regions (BCRs) or groups of BCRs. Mandalay NWR contributes to the goals of each of the relevant regional plans and of the NABCI by participating in the Gulf Coast Joint Venture and by contributing directly to bird conservation through the actions detailed in this plan.

North American Waterfowl Management Plan

The North American Waterfowl Management Plan (NAWMP Committee 2004) arose out of an agreement between the United States and Canada to conserve and restore habitat for waterfowl. The first version of the plan was signed by the two nations in 1986. In 1994, Mexico also signed on, making the effort truly continental in scale. Regional partnerships called Joint Ventures composed of individuals, hunting and fishing groups, conservation organizations, and local, state, provincial, and federal governments were formed under the NAWMP. Mandalay NWR falls within the geographic area covered by the Gulf Coast Joint Venture (GCJV). The GCJV is divided geographically into six initiative areas, one of which is the Mississippi River Coastal Wetlands Initiative Area (MRCWIA) of southeastern Louisiana, which includes Mandalay NWR. The goal of the Mississippi River Coastal Wetlands Initiative (Wilson, Manlove & Esslinger 2002) is to "provide wintering and migration habitat for significant numbers of dabbling ducks, diving ducks, and snow geese, as well as year-round habitat for the mottled duck."

Mandalay NWR will contribute to the goals of the NAWMP, GCJV, and MRCWI by providing 4,416 acres of fresh marsh to sustain resident and wintering waterfowl.

North American Waterbird Conservation Plan

The North American Waterbird Conservation Plan (Kushlan et al. 2002) is a continental-scale conservation plan which focuses on waterbirds not covered under NAWMP or other NABCI plans. Developed by Waterbird Conservation for the Americas, the document gives population and habitat goals for 210 species of waterbirds across North and Central America. A regional plan has been developed for the southeastern United States (Hunter et al. 2006). Marsh habitat on Mandalay NWR supports waterbirds year-round, and habitat requirements of waterbirds are complementary to those of the resources of concern for the refuge.

U.S. Shorebird Conservation Plan

The United States Shorebird Conservation Plan (Brown et al. 2001) was developed to promote the conservation of shorebirds within the United States. Mandalay NWR is located within the Lower Mississippi, Western Gulf Coast Shorebird Planning Region, for which a regional plan has been developed (Elliott & McKnight 2000). This plan divides the Gulf Coast Shorebird Planning Region into subregions. Mandalay NWR falls within the Mississippi River Coastal Wetlands subregion. Mandalay NWR contributes to the goals of the Lower Mississippi/Western Gulf Coast Shorebird Conservation Plan by providing undisturbed foraging and roosting, non-beach habitat.

Partners in Flight Bird Conservation Plan

The Partners in Flight North American Landbird Conservation Plan (Rich et al. 2004) was developed during the 1990s with funding from the National Fish and Wildlife Foundation. Continental in scope, this plan identifies landbird species of conservation concern and gives quantitative goals for their conservation. In addition to the over-arching plan, a series of regional plans focused on bird conservation regions (BCRs), have been written, including one for the Gulf Coastal Prairie region (Vermillion et al. 2008), which includes Mandalay NWR. Limited bottomland hardwood (175 acres) and cypress-tupelo (75 acres) habitat on Mandalay NWR provide breeding, migrating, and wintering habitat for landbirds, including certain of the resources of concern and species whose habitat requirements are complementary to those of the resources of concern.

Louisiana Comprehensive Wildlife Conservation Strategy

Louisiana's *Comprehensive Wildlife Conservation Strategy* (Lester et al. 2005) was published in 2005 after consultation with a broad group of interested parties including private organizations, agencies, academic institutions, and the general public. The plan details the conservation needs and strategies for aquatic and terrestrial systems across the state and lists a number of high-priority actions for imperiled species and systems. In the Gulf Coast Prairies and Marshes ecoregion, where Mandalay NWR is located, freshwater marsh is listed as a high priority for conservation action because of the high threat level it faces and the number of species of concern that it supports. Bottomland hardwoods and cypress-tupelo swamp ranked low in terms of priority and threat status in this ecoregion. Strategies described in Lester et al. (2005) to which management actions detailed in this HMP will contribute include:

- Freshwater Marsh
    - Shorebirds, Wading Birds
        - Continue to encourage the creation/enhancement/maintenance of high-quality habitat across Louisiana.
    - Waterfowl
        - Work with DU, DW, and the Service to assure that quality habitat, including refuge from hunting and other disturbance, is distributed across the landscape.

REGIONAL PLANS AND INITIATIVES

Landscape Conservation Cooperatives

Landscape Conservation Cooperatives (LCCs) were set up by the Service and the U.S. Geological Survey to support the goals of Strategic Habitat Conservation (SHC). LCCs are partnerships of state, federal and tribal agencies, non-governmental organizations, academic institutions, and others which provide scientific expertise and promote collaboration in order to achieve conservation at landscape scale. Twenty-two LCCs have been created across the nation, including the Gulf Coastal Plains and Ozarks LCC, for which a development and operations plan has been written (U.S. Fish and Wildlife Service 2009).

Coastal Wetlands Planning, Protection, and Restoration Act

The Coastal Wetlands Planning, Protection, and Restoration Act program (CWPPRA or "Breaux Act"), (Public Law 101-646), provides for targeted funds to be used for planning and implementing projects that create, protect, restore, and enhance wetlands in coastal Louisiana. Passed in 1990 and authorized until 2019, the federal funds created by CWPPRA are managed by the CWPPRA Task Force, a group composed of the State of Louisiana and five federal agencies including the Service. Funds provided through this legislation have been instrumental in shoreline stabilization and other projects on Mandalay NWR.

1.3.4.3 Coast 2050

In 1998, a plan called "Coast 2050: Toward a Sustainable Coastal Louisiana" was developed by state and federal agencies working together as the Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. The plan seeks to address coastal erosion and land loss along the state's shoreline by laying out a series of strategic goals and strategies. In this plan, Mandalay NWR is located in Region 3 (Terrebonne, Atchafalaya, Teche/Vermilion). The plan emphasizes that immediate attention should be placed in the Barataria Basin with ecosystem strategies to restore swamps, restore and sustain marshes, protect bay/lake shorelines, and restore barrier islands and Gulf shorelines.

II. Background, Inventory, and Habitat Descriptions

LOCATION

Mandalay NWR is located 7 miles southwest of Houma, Louisiana, in Terrebonne Parish. The refuge consists mostly of freshwater marsh, with a ridge (natural levee) supporting a small acreage of bottomland hardwoods and adjacent cypress-tupelo swamp. Nearby conservation lands include state wildlife management areas (WMAs) and other state lands, as well as easements administered by the U.S. Army Corps of Engineers, mostly in the Atchafalaya basin (Figure 1). The refuge is one of eight administered by the Service's Southeast Louisiana NWR Complex in Lacombe, Louisiana.

MANAGEMENT UNITS

The refuge is divided into six management units, ranging in size from 144 acres to 2,452 acres (Figure 2). A short description of each unit is given in Table 1.

Figure 1. Location of Mandalay NWR and other nearby conservation lands

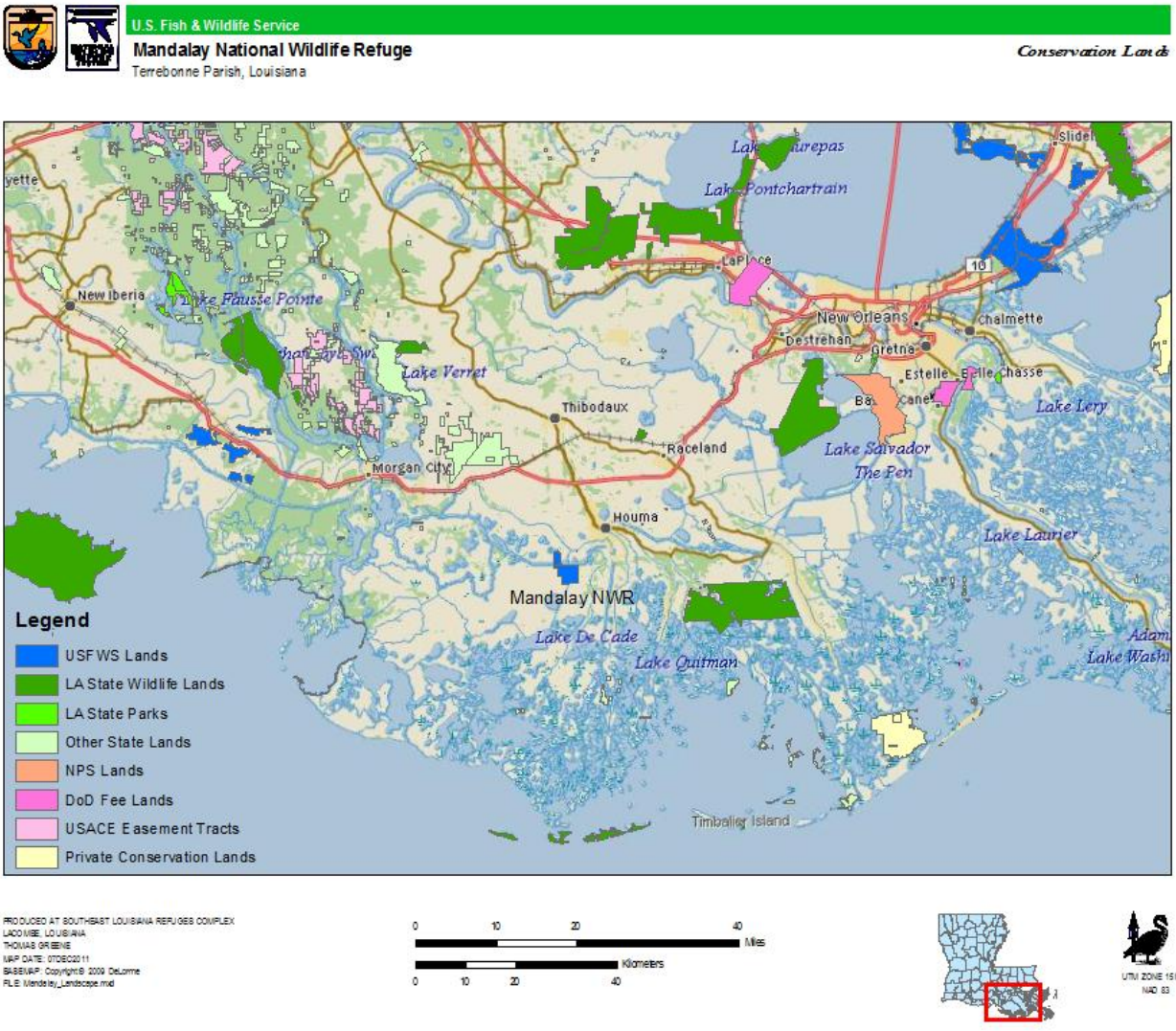


Figure 2. Mandalay NWR management units

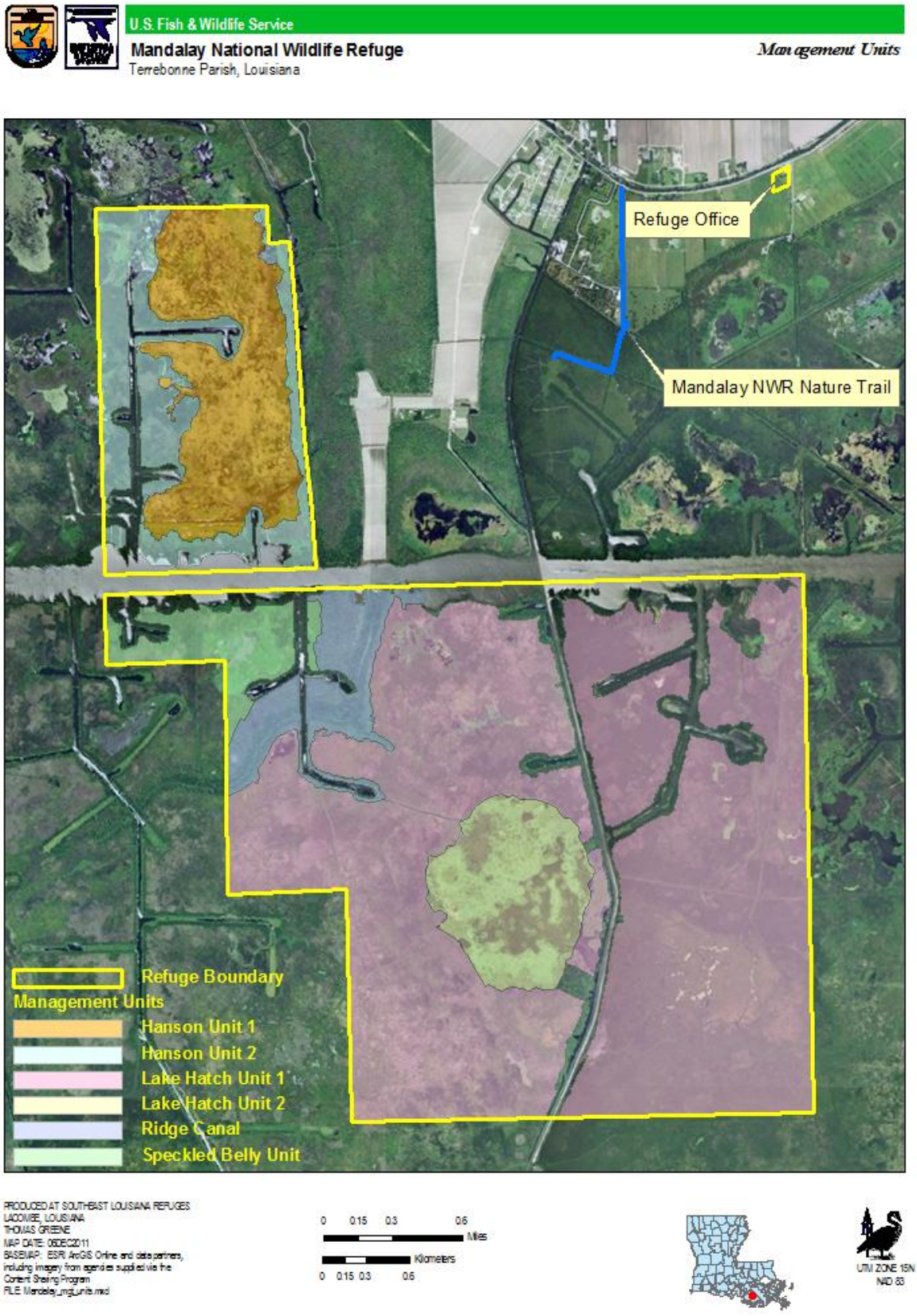


Table 1. Management unit descriptions for Mandalay NWR, Terrebonne Parish, Louisiana

Unit	Size (acres)*	Description
Hanson 1	432	This unit consists mostly of shallow open water. Submerged and floating-leaved rooted aquatic vegetation dominates. Species include American lotus (*Nelumbo lutea*), white water lily (*Nymphaea odorata*), pond lily (*Nuphar lutea*), coontail (*Ceratophyllum demersum*), pondweed (*Potamogeton* spp.), and Carolina fanwort (*Cabomba caroliniana*). Invasive floating plants, including water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta, S. minima*), and Cuban bulrush (*Oxycaryum cubense*), require management to prevent their covering the surface of the pond and shading out the submerged aquatic vegetation. This unit is open to waterfowl hunting and contains five duck blinds, which are allocated by lottery.
Hanson 2	331	Hanson Unit 2 is mostly freshwater marsh, dominated by bulltongue (*Sagittaria lancifolia*), with maidencane (*Panicum hemitomon*), bulrush (*Schoenoplectus spp.*), cattail (*Typha spp.*), and others. Canals provide access to this unit from the GIWW. An area along the southern edge of this unit was restored to marsh with the application of dredge spoil from the GIWW. At this writing (January 2012), the restored area is dominated by weedy dicots (*Ludwigia octovalvis, Sesbania punicea*).
Lake Hatch 1	2,452	This largest unit of the refuge mostly consists of freshwater marsh, dominated by maidencane and cattails. As in the Hanson Unit 2, canals provide access for managers and visitors. The only active hydrocarbon extraction unit on the refuge is in the northeastern corner of this unit. The northern edge of this unit contains several different experimental breakwater structures designed to stop and reverse bank erosion along the GIWW.
Lake Hatch 2	284	This unit consists of the open-water pond known as Lake Hatch. As is the case in Hanson Unit 1, floating mats of invasive plants threaten the native vegetation and convert valuable open shallow water habitat to floating "marsh," which has less value for waterfowl and other resources of concern.
Ridge Canal	183	The Ridge Canal supports the refuge's only bottomland hardwood habitat. It consists of a natural levee, known as Hatch Ridge, along an old distributary channel of Bayou Black and small areas of spoil bank, which line canals and the GIWW. Dominant tree species include sugarberry (*Celtis laevigata*), red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), water oak (*Quercus nigra*), Nuttall oak (*Quercus texana*), and black willow (*Salix nigra*).
Speckled Belly	144	This unit, adjacent to the GIWW, consists of freshwater marsh with areas of open water.

** Acreages were calculated using ARC-GIS (ESRI 2009), and thus are approximate. Total does not include canals, spoil banks, or eroded areas along the GIWW, all of which are included in the refuge total acreage of 4,416.*

PHYSICAL FEATURES

CLIMATE

Climate in this region is subtropical, with mild winters and warm, humid summers. Precipitation during the summer months is mostly associated with thunderstorms, and is typically intense and of short duration. During the cool season, precipitation is mostly caused by frontal passage, and is typically less intense and of longer duration. Freezes occur most years, but are generally mild and of short duration. Frost-free (i.e., ≥ 32oF) period 5 years out of 10 is 296 days; 2 years out of 10 it is 319 days. Temperatures never fall below 24 oF 8 years out of 10 (Natural Resources Conservation Service n.d.).

Precipitation

Annual precipitation at Mandalay NWR averages 63.7 inches and falls almost exclusively as rain. Rainfall peaks during the summer months, when frequent, sometimes intense, thunderstorms raise monthly totals above 6 inches. Monthly totals during the fall and spring are generally below 5 inches, with October being the driest month (Figure 3). Winter precipitation mostly results from the passage of cold fronts and is typically of broader extent and lower intensity than summer rainfall. Tropical storms impact the Louisiana coast every 1.6 years, and hurricanes every 3.3 years (Roth 1998). Areas in the path of one of these storms can receive significant rainfall in addition to wind and storm surge.

Temperature

Air temperatures at Mandalay NWR are moderated by the Gulf of Mexico, which buffers the temperature extremes associated with continental air masses. Normal temperature maxima for January and July, respectively, at Houma, Louisiana, are 63oF and 91oF; minima are 43oF and 73oF (Natural Resources Conservation Service n.d.). On average, temperature falls below freezing 11 days each year, mostly in December and January. Mean and monthly average temperature maxima and minima are presented in Figure 4.

Figure 3. Mean monthly precipitation, Houma, Louisiana, 1971-2000 (Natural Resources Conservation Service n.d.).

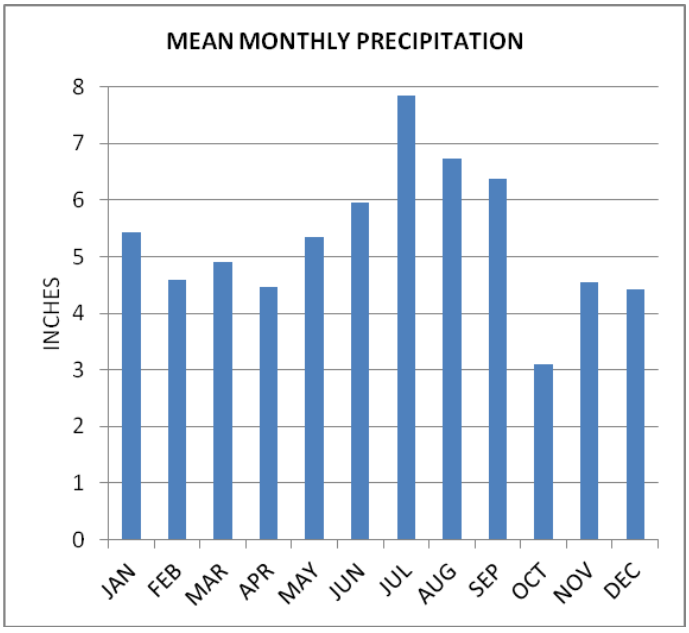
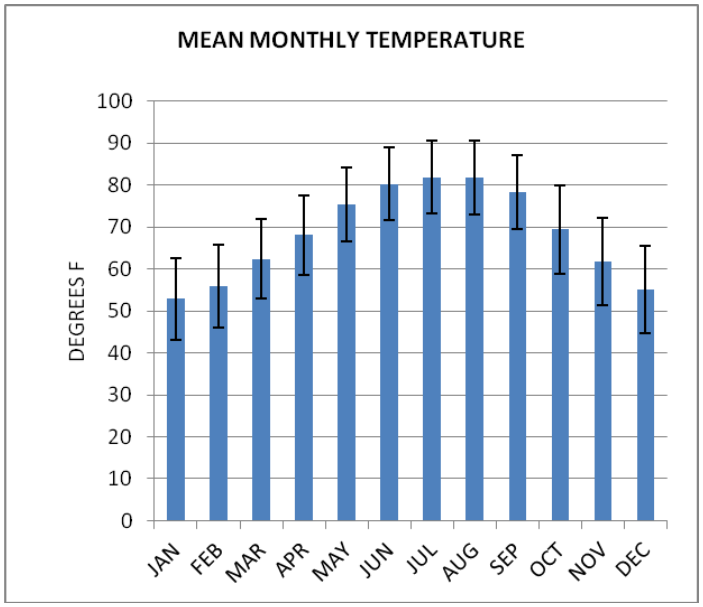


Figure 4. Mean temperature, degrees Fahrenheit, with average daily minima and maxima, by month at Houma, LA, 1971-2000 (Natural Resources Conservation Service n.d.).



Tropical Cyclones

Named tropical storms (i.e., storms with sustained winds at least 35 knots (64.8 km/h)), impact southeastern Louisiana on average three or four times per decade (Global Security.org 2005). Tropical cyclones are an important feature of the climate of southern Louisiana. These storms have shaped the landscape, vegetation, and ecology of the area for millennia, and continue to do so today. Storm surges can completely reshape coastal landforms, and periodic inundation with saltwater restricts the range of vegetation types that can occupy an area. High winds associated with these storms also affect growth forms of woody vegetation, favoring windfirm species like baldcypress and longleaf pine, and those with above-ground growth forms that are resistant to wind like live oak, and providing disturbance which increases biodiversity (Merry, Bettinger & Hepinstall 2009) (Mitchell & Duncan 2009). Mandalay NWR is located within 25 miles of the coast, and elevations on the refuge range from 0-3 feet above msl. Most of the refuge is subject to inundation in even moderate storm surges. High winds and rain associated with tropical cyclones can be expected. Intensification of tropical cyclones associated with global climate change will increase storm effects on the refuge.

GEOLOGY AND TOPOGRAPHY

The entire area surrounding Mandalay NWR is on alluvial deposits originating from the Mississippi River and its antecedents. Mandalay NWR lies within the Penchant sub-basin of the Terrebonne Basin, a region of low-lying marshland south of Bayou Black and Bayou Boeuf, east of the Atchafalaya River, and west of Bayou DuLarge. Bayous DuLarge and Black are part of an old distributary network of the Mississippi River, which flowed south through Bayou Lafourche (Terrebonne Parish Office of Coastal Preservation and Restoration 2009). Bayou Lafourche is now cut off from the Mississippi River by a levee at Donaldsonville. High ground in the vicinity of the refuge is mostly on natural levees of bayous, while land away from waterways is low-lying and poorly drained. Essentially all reasonably well-drained

soils in Terrebonne Parish are cleared and under cultivation or developed for urban use. The refuge is now flooded by overflow from the Atchafalaya River, which is connected by the GIWW and Bayou Black to the vicinity of Mandalay NWR.

HYDROLOGY

The hydrology of Mandalay NWR and the surrounding area has been modified significantly from pre-settlement conditions by the construction of levees and canals, by water management upstream on Bayou Lafourche, and most significantly by the GIWW. Bank erosion from the GIWW threatens the refuge's marsh habitat. Flooding from the Atchafalaya River affects the refuge. None of the water management infrastructure is under the control of refuge managers.

Figure 5. Mississippi Flyway migration route

SOILS

Soils on Mandalay NWR are predominantly mucks and are all subject to at least occasional flooding. A small area of mineral soil map units (clays and silty clay loams) is found in the Ridge Canal unit, and dredge spoil areas along the GIWW and other canals are mapped as aquents. Detailed soil information is presented in Appendix E.

FLYWAYS

Mandalay NWR lies at the southern end of the Mississippi Flyway (Figure 5), one of four migration corridors in North America.

Figure 5. Mississippi Flyway migration route

ECOSYSTEM CONTEXT

Mandalay NWR straddles the GIWW in an area of freshwater marsh bounded on the east by the natural levees of Bayou du Large, on the north by the natural levees of Bayou Black, on the south by brackish and saline marshes and the coast, and on the west by the mouth of the Atchafalaya River. Marshlands in the vicinity of the refuge are generally in natural vegetation, although they are dissected by numerous canals. Higher ground near waterways is nearly all cleared for agriculture or urban use. Protected lands near the refuge are primarily state WMAs (Figure 6).

HISTORIC CONDITION OF REFUGE HABITATS

Before European settlement, the area that would become Mandalay NWR was presumably dominated by freshwater marsh, with bottomland hardwoods on higher ground near waterways, fringed by baldcypress-tupelogum swamp. Seasonal flooding and periodic inundation by storm surges from tropical cyclones would have been the major ecosystem drivers. Elevation, then as now, would have been the critical variable determining vegetation type. Major disturbances would have included windthrow and saltwater intrusion from tropical cyclone storm surge, winds, and tornadoes. Closer to the Gulf, intermediate and brackish marsh vegetation types would have covered the most low-lying areas, as they do now. Fire return intervals in marsh are debated, but fire would have been relatively frequent there and much less frequent in the forested areas, especially the baldcypress-tupelogum swamps.

PREHISTORIC HUMAN OCCUPATION

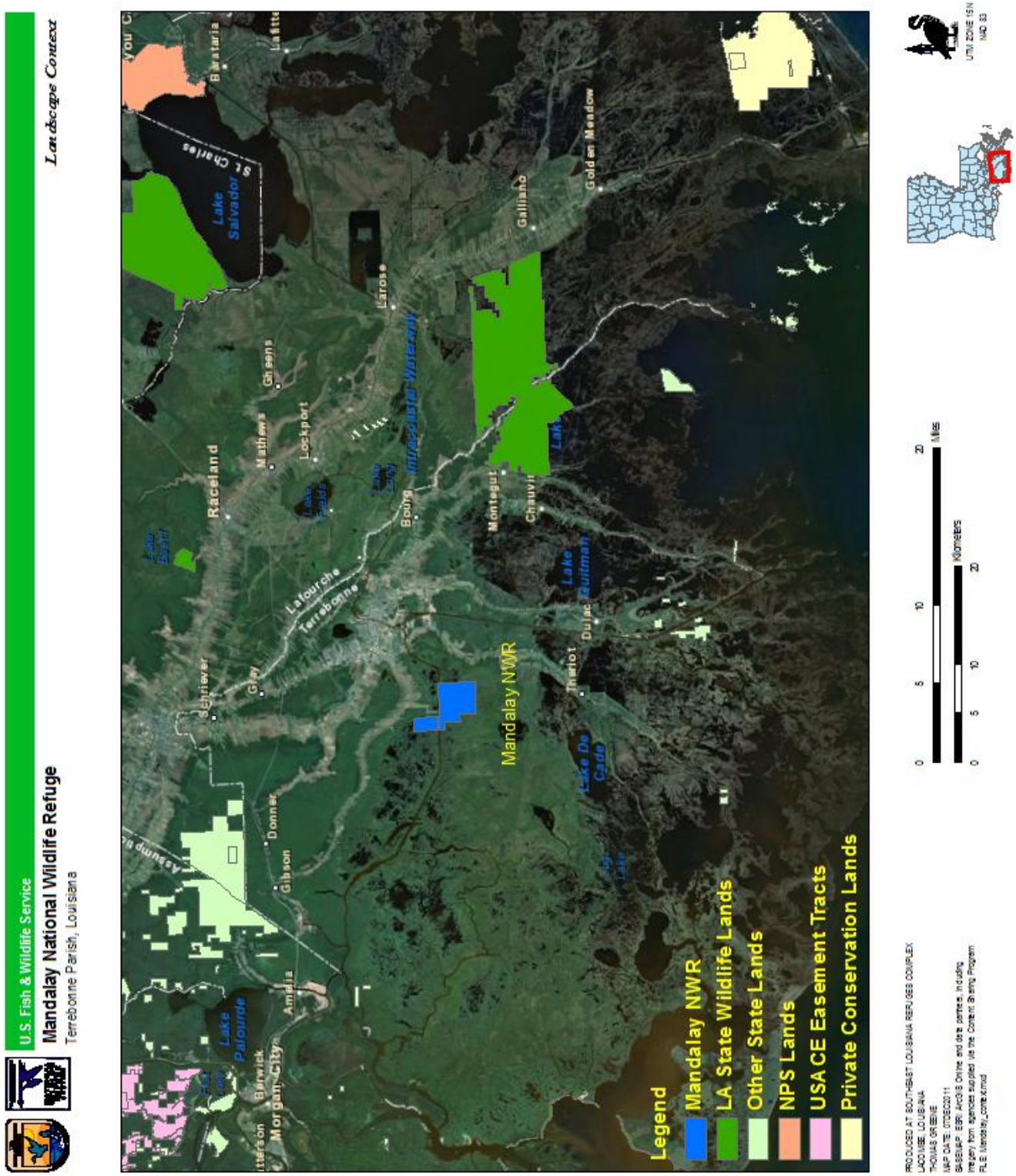
Native American peoples inhabited southern Louisiana and the Gulf coast for millennia before Europeans explored, then colonized the region beginning in the 16th Century. Early inhabitants of Terrebonne Parish were mound builders and left traces of their culture on the landscape in the form of burial mounds. However, by the time European settlers arrived in the 18th Century, these early inhabitants were gone (Hebert 2001). It can be assumed that these early Americans, like other prehistoric North American peoples, used fire as a tool to manage their landscape, and probably had the effect of decreasing the fire return interval on lands that they burned, including the marshes of Terrebonne Parish (Pyne 1982).

HISTORICAL HUMAN OCCUPATION

Spanish exploration of the Gulf coast began as early as 1502, and by the end of the 17th Century, Spanish and French settlements had been established in what was to become Louisiana (Kniffen 1968). France ceded Louisiana to the Spanish in 1763, but regained control of the territory east of the Red River, exclusive of the Florida Parishes, in 1803, prior to its sale to the United States later that year (Haggard n.d.).

European colonization of south Louisiana began in earnest after French-speaking Acadians were expelled from Nova Scotia by the British, and began to settle in the area in 1765. The Acadians, or "Cajuns," as they became known, were farmers, herders, fishers, and hunters, and began transforming the landscape to further those pursuits (Hebert 2003). Immigrants of many origins, including Native Americans from other regions of the continent, African-American, African-Caribbean, English, German, Irish, and Spanish joined the Acadians in southern Louisiana and contributed to the unique culture found there today (Owens 1997).

Figure 6. Protected lands and natural features near Mandalay NWR



Clearing of arable lands on natural levees of bayous in the area began during this time, eventually leading to the loss of most bottomland hardwood habitat in the vicinity of Mandalay NWR. Farming increased sediment inputs into streams, and was accompanied by the construction of ditches, levees, and canals. Waterways have been dredged, straightened, bypassed, and channelized in order to improve navigation, drainage, irrigation, and water supply, and, since 1929, for access to oil and gas production facilities (Sell & McGuire 2008). As a result, coastal wetlands are being lost at unprecedented rates, despite their critical importance to both terrestrial and marine environments.

RECENT HISTORY

- 1929–Discovery of oil in Terrebonne Parish (Sell & McGuire 2008)
- 1962–Completion of the Houma Navigation Canal
- 1996–Mandalay NWR Established (May 2)
- 2005–Hurricanes Katrina and Rita
- 2008–Hurricanes Gustav and Ike

CURRENT HABITAT CONDITIONS

VEGETATION TYPES

Mandalay NWR supports three general vegetation types, listed in Table 2. Although formal characterization of the vegetation types on the refuge has not been conducted, it appears that these three types, baldcypress-tupelo swamp, bottomland hardwood forest, and fresh emergent and shrub/flotant marsh (including open-water ponds), correspond, at least in part, to the following six International Vegetation Classification System (IVCS) Associations (NatureServe 2011). Note: Alliances in the IVCS are under review at this writing (February 2012) and are not available on the NatureServe website. Intersecting or corresponding SAF Forest Types (Eyre (ed.) 1980) are given for reference when applicable. A generalized map of habitat types on the refuge, digitized from imagery, is presented in Figure 7.

Fraxinus pennsylvanica – Ulmus americana – Celtis laevigata / Ilex decidua Forest CEGL002427

Alluvial forests of this association are dominated by green ash, American elm, and either sugarberry (south, including Mandalay NWR) or hackberry (north), and have a number of canopy associates depending on overlapping species ranges. On Mandalay NWR, common canopy associates are water oak (*Quercus nigra*), water hickory (*Carya aquatica*), sweetgum (*Liquidambar styraciflua*), swamp blackgum (*Nyssa biflora*), and red maple (*Acer rubrum*). Shrubs include swamp dogwood (*Cornus drummondii*) and deciduous holly (*Ilex decidua*). Also common in this forest association are lianas, especially Virginia creeper (*Parthenocissus quinquefolia*), trumpet creeper (*Campsis radicans*), and poison ivy (*Toxicodendron radicans*) (NatureServe 2011). The association is classified under the Macrogroup Northern and Central Floodplain Forest and Scrub and in the *Acer saccharinum – Fraxinus pennsylvanica – Platanus occidentalis* Floodplain Group. The small area of bottomland hardwood forest on Mandalay NWR appears to map more or less closely to this association. The association intersects with the SAF forest type Sugarberry – American Elm – Green Ash: 93 (Eyre (ed.) 1980).

Figure 7. Habitat types on Mandalay NWR

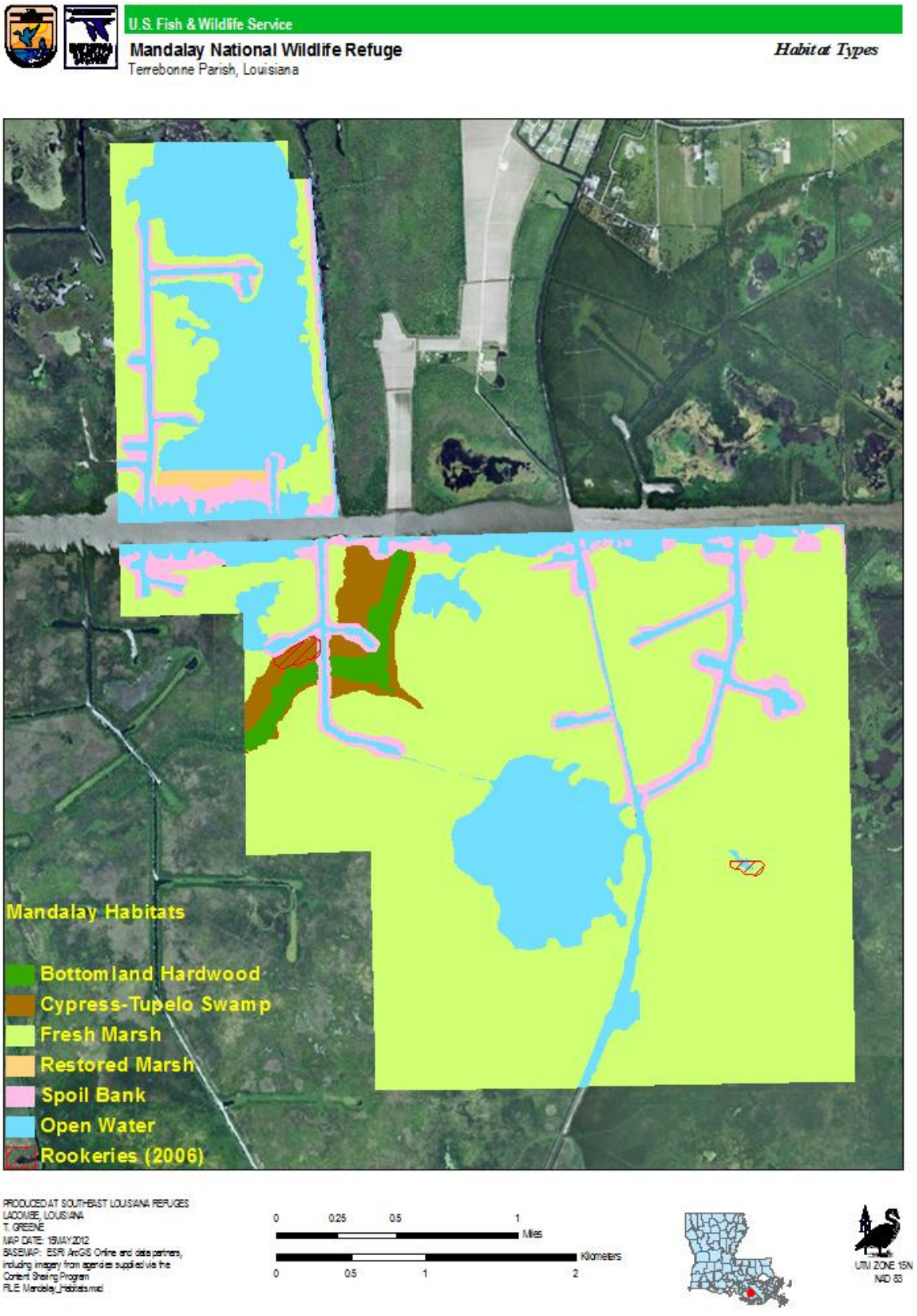


Table 2. Habitat types and associated acreages found on Mandalay NWR

Habitat Type	Acres	Management Units	Habitat Conditions
Freshwater Marsh/open water	3,700	Hanson Unit 1 and 2, Lake Hatch Unit 1 and 2, Speckled Belly Unit. Open water is also found in canals throughout the refuge.	Freshwater marsh on Mandalay NWR is either flotant or rooted/emergent, and can be dominated by bulltongue, maidencane, cattails, or a mixture of these. Flotant marsh is usually dominated by maidencane, and can include waxmyrtle. Since Hurricanes Katrina and Rita, cattails have become much more prominent, perhaps in response to disturbance from the storms. Cattails also tend to seed in where nutria destroy marsh vegetation. Flotant marsh and rooted, emergent marsh are interspersed on a fairly fine scale and are mapped together in this plan.
Cypress-Tupelo Swamp	86	Ridge Canal Unit	These habitats have some large, old baldcypress trees, and sustained some damage in recent storms.
Bottomland Hardwoods	61	Ridge Canal Unit	Bottomland hardwood areas of the Ridge Canal are found on a narrow ridge of Cancienne soils along Hatch Ridge. This habitat is mostly sugarberry/American elm/green ash forest, and has been invaded by Chinese tallow.
Spoil Banks	276*	All units	Spoil banks are generally dominated by early successional woody species. Chinese tallow is common along most areas.

**Note: Spoil Bank acreage is not given in the CCP, and was determined by measuring a digitized GIS layer. Spoil banks support some early successional hardwood habitat (about 103 acres) not included in the total for bottomland hardwood in this table. Acreage does not total to refuge total (4,416) because area within the GIWW (not owned by Service) was excluded from this table.*

Taxodium distichum – (Nyssa aquatica) / Forestiera acuminata – Planera aquatica Forest (CEGL002421)

This association is classified under the *Taxodium distichum – Nyssa aquatica* Floodplain Forest Group. This association includes baldcypress-water tupelo forests in the Mississippi River Alluvial Plain and adjacent portions of the Gulf Coastal Plain. Swamp forests in this association are dominated by baldcypress and water tupelo. Other trees which may be present include water hickory (*Carya aquatica*) and overcup oak (*Quercus lyrata*). Shrubs can include buttonbush (*Cephalanthus occidentalis*), Virginia-willow (*Itea virginica*), and red maple (*Acer rubrum*), among others (NatureServe 2011). On Mandalay NWR, these forests occur along the low fringes of natural levees in the Ridge Canal unit. This association is related to SAF Forest type #102, Baldcypress – Tupelo (Eyre (ed.) 1980).

Morella cerifera – Panicum hemitomon Flotant Marsh Herbaceous Vegetation (CEGL007834)

This type of marsh occurs on floating mats of peat. The association is classified under the Macrogroup Atlantic and Gulf Coastal Plain Freshwater Tidal Marsh and in the Group *Hibiscus moscheutos – Spartina cynosuroides – Zizania aquatica* Freshwater Tidal Marsh. This association occurs in the Lake Hatch units south of the GIWW.

Sagittaria lancifolia – Typha spp. – Ludwigia spp. Herbaceous Vegetation (CEGL007894)

This association is a floating or rooted marsh type dominated by bulltongue, with cattails and ludwigia as major associated species. This association appears to be the dominant marsh type in Hanson Unit 2 of Mandalay NWR. Classification for this association is the same as for CEGL007834 above, and they often occur interspersed on the Louisiana Delta Plain (NatureServe 2011).

Panicum hemitomon Semipermanently Flooded Herbaceous Vegetation (CEGL004665)

This association is a common and broadly defined vegetation type which is probably represented on the refuge, although mapping has not been done. Species commonly associated with maidencane in this type include cutgrass (*Cladium mariscus ssp. jamaicense*), bulrush (*Schoenoplectus californicus*), bulltongue (*Sagittaria lancifolia*), and others. It is classified in the Macrogroup Atlantic and Gulf Coastal Plain Freshwater Tidal Marsh and in the group *Hibiscus moscheutos – Spartina cynosuroides – Zizania aquatica* Freshwater Tidal Marsh.

Nuphar advena – Nymphaea odorata Herbaceous Vegetation (CEGL00236)

This association appears to dominate open water areas in Hanson Unit 1 and Lake Hatch Unit 2 on Mandalay NWR. The association is dominated by rooted, floating-leaved herbs, either broadleaf pond-lily or white water-lily, or both. Common associated plant species include watershield (*Brasenia schreberi*), pondweeds (*Potamogeton spp.*), and duckweed (*Lemna spp.*). Submersed plants include cabomba (*Cabomba caroliniana*), coontail (*Ceratophyllum demersum*), and grassleaf mudplantain (*Heteranthera dubia*). This association is classified in the Macrogroup Eastern North American Freshwater Aquatic Vegetation, and in the Group *Nymphaea odorata – Stuckenia pectinata – Potamogeton* spp. – Freshwater Aquatic Vegetation.

Habitat Changes from Historic to Current Condition

Ecosystems are dynamic, changing in response to environmental shifts, disturbance, and addition or loss of species. In healthy ecosystems, robust ecosystem processes respond to these changes without catastrophic losses of biodiversity or major functions. In today's highly modified landscapes, large-scale natural processes (e.g., fire, flooding, and sediment deposition) have been disrupted, leading to loss of ecosystem health and resiliency. Refuge managers must strive to restore or mimic (i.e., either restore on a small scale or re-create essential elements of) ecosystem processes in order to maintain biological integrity, diversity, and environmental health, and create habitat conditions favorable for the resources of concern. Often, this means traditional management actions (e.g., water management, prescribed fire, forest management, control of exotic invasive organisms) are required. Strategies such as these are generally most successful when conducted in the context of maintaining or restoring ecosystem processes.

Changes in habitats from historic to present on Mandalay NWR and in Terrebonne Parish are mostly anthropogenic, although natural subsidence of the Louisiana coast (NASA 2008) (Shinkle & Dokka 2004) contributes to the conversion of drier to wetter types over time. Anthropogenic forces which have altered habitats over the past two centuries include modification of hydrology and drainage patterns by construction of canals, levees, and ditches, clearing of land for agriculture and urban uses, forest resource extraction, introduction of exotic species, and climate change. Habitat changes on and near Mandalay NWR that have resulted from these activities include the following:

- Loss of most of the bottomland hardwood forest habitat in the region;
- Conversion of open water habitat to floating mats of exotic plants;
- Damage to marsh vegetation by exotic animals;
- Construction of canals, which provides both deepwater habitat as well as elevated areas (spoil banks) within marshes and swamps;
- Changes in fire frequency due to fragmentation of marsh by canals and fire suppression.

Each of these changes will be discussed in more detail below.

LOSS OF BOTTOMLAND HARDWOOD FOREST HABITAT

The natural levees of Bayou Black and other bayous in the region once supported bottomland hardwood forests. Higher sites near the watercourses may have been vegetated with drier-type forests, dominated by oaks, while wetter areas would have been dominated by green ash – American elm – sugarberry forest, as the remnants are today. Most of this land, because it is valuable as farmland, was cleared during colonial times in the 18th and early 19th Centuries for agricultural production, which use continues today.

CONVERSION OF OPEN WATER TO EXOTIC FLOATING MAT VEGETATION

Open water habitat in Hansen Unit 1 and Lake Hatch Unit 2, as well as in canals, is infested with salvinia (*Salvinia molesta, S. minima*), water hyacinth (*Eichhornia crassipes*), and Cuban bulrush (*Oxycaryum cubense*), the combination of which creates a dense, thick floating mat of vegetation which is nearly impenetrable to boat traffic, shades out native submerged and rooted, floating-leaved plants valuable for wildlife, and creates hypoxic conditions in the water column.

DAMAGE TO MARSH VEGETATION BY EXOTIC ANIMALS

Many exotic animal species can be found on Mandalay NWR, but two are significant problems for managers: feral hogs (*Sus scrofa*) and nutria (*Myocastor coypus*). Feral hogs pose a number of threats to wildlife and native systems on the refuge. Hogs damage natural vegetation through their feeding and rooting behavior, they negatively impact native wildlife populations through competition and direct predation, and they are reservoirs of diseases and parasites which can affect native animals, livestock, and even humans (Missouri Department of Conservation n.d.; Miller & Synatzke 1993). By rooting and digging for food, feral hogs destroy fragile wetland plants and cause soil erosion and changes in successional patterns. They are omnivores, and will eat acorns, tubers, fruits, roots, and other plant material, decreasing the availability of these resources for native wildlife. They will also prey on eggs of ground-nesting birds and reptiles, and on the young of mammals such as rabbits and deer (Missouri Department of Conservation n.d.). Nutria are herbivorous aquatic rodents native to South America, which damage marsh habitats in the southern United States by consumption of emergent plants and burrowing. Impacts can range from heavy grazing to conversion to open water. State surveys of nutria damage show that the bulk of nutria impacts in Louisiana are in Terrebonne Parish, where total damaged area can exceed 12,000 acres in a single year (Marx, Mouton & Linscombe 2004).

CONSTRUCTION OF CANALS AND SPOIL BANKS, AND ASSOCIATED BANK EROSION

The demands of transportation, commerce, and resource extraction have resulted in construction of a network of canals throughout coastal Louisiana, including Mandalay NWR. These canals provide open, relatively deepwater habitat fringed by spoil banks, which serve as narrow lanes of high ground, where only swamp or marsh existed before. Open water is a natural component of freshwater marsh; watercourses within the marsh allow water to flow through and provide refugia for aquatic organisms during periods of extreme heat, cold, or drought. However, deep, typically straight, channels constructed through marsh habitat change flow patterns and rates, can serve as channels for saltwater intrusion, and create habitat for invasive exotic plants to take hold. On Mandalay NWR, canals are infested with floating exotic invasive aquatic weeds, primarily water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta, S. minima*), and Cuban bulrush (*Oxycaryum cubense*). These plants form floating mats which impede boat traffic, shade out rooted aquatic plants, and cause anoxic conditions in the water column. Spoil banks on the refuge are vegetated by early successional hardwood species, including sweetgum, red maple, black willow, water oak, and sugarberry. Chinese tallowtree (*Triadica sebifera*), an exotic invasive tree, is also present on spoil banks over much of the refuge. In large canals such as the GIWW, bank erosion, either through the action of vessel wakes or wind-driven waves, can widen the channel at the expense of marginal habitats. Erosion has become a problem along the GIWW on Mandalay NWR, where waves have washed away spoil banks and created open water “bays” in place of marsh (U.S. Geological Survey 2012).

CHANGES IN FIRE REGIME

Alteration of fire regimes is probably one of the first ways that humans changed their environment, and most human-influenced landscapes exhibit some degree of change due to modification of the fire regime (Pyne 1995). Prehistoric fire regimes in coastal marshes in Louisiana are not well known; however, it is likely that early human inhabitants modified the return interval and seasonality to suit their purposes (Pyne 1982). European settlers brought new technologies which allowed larger-scale landscape modifications, most notably the construction of canals and other fire breaks in coastal marshes. This practice tended to break the landscape into smaller units and may have decreased fire frequency by reducing the area affected by each individual fire. Humans also affect the seasonality of fire. In the Everglades, lightning fires are concentrated in the early mid-growing

season, when fire intensities are typically lower, while anthropogenic fires peak during the dormant season when fuels are cured (Slocum et al. 2007). It is possible that a similar shift occurred with human occupation of southern Louisiana.

CHANGES ASSOCIATED WITH GLOBAL CLIMATE CHANGE

Anthropogenic climate change, a result of elevation of atmospheric carbon dioxide levels from fossil fuel consumption, widespread deforestation and release of other "greenhouse gases," such as methane from various sources, is a threat not only to conservation of natural resources, but also to the global human population. Recent observed changes including elevated mean temperatures, shifts in precipitation patterns, and sea level rise, are almost certainly only harbingers of much worse to come (IPCC 2007). That these changes are anthropogenic is no longer seriously in question; numerous well-designed studies have implicated human activities in elevation of greenhouse gases and other known causes of global climate change (CCSP 2009). For Mandalay NWR, the most important consequences of climate change are sea level rise and an increase in the frequency and/or intensity of tropical cyclones. Additional consequences will likely be shifts in phenology and species distribution, with more temperate flora and fauna being gradually replaced by subtropical and tropical species. The southeastern United States is more vulnerable to climate change because of its biodiversity, low-lying coast, and highly fragmented landscape (Smith 2004; Karl, Melillo & Peterson 2009). The Service has laid out its strategic plan for addressing climate change (U.S. Fish and Wildlife Service 2010).

Climate change effects which can be expected on Mandalay NWR include increased temperatures, increased fall precipitation coupled with decreased summer precipitation, increased frequency and severity of droughts, increased intensity of hurricanes with possible increased frequency as well, and rising sea level. Local subsidence will exacerbate the effects of global sea level rise on southern Louisiana. Management of the refuges will certainly be affected by these changes, though the details are uncertain. Some likely scenarios, however, include the following:

- Increased temperatures and concomitant decreases in severity of cold weather may lead to changes in species composition, including increases in tropical and subtropical exotic invasives such as water hyacinth, giant salvinia, tallowtree, and nutria. Additional management actions may be required to control these species in this case.
- If seasonal precipitation distribution in south Louisiana becomes more uneven, salinity fluctuation in marsh and tidal swamp habitat may be wider, leading to changes in plant and animal communities and further loss of organic soil through oxidation.
- More intense tropical storms will lead to recurring impacts similar to that experienced from recent hurricanes–conversion of marsh to open water, and damage to refuge infrastructure.
- Rising global sea level, combined with local subsidence caused by geologic forces, will lead to changes in relative sea level. Since most of the refuge lies below 3 feet in elevation, rising sea level will lead to conversion of refuge habitats to brackish or saline marsh, and eventually to open water.
- Changes in temperature and precipitation regimes will have unpredictable effects on habitats and species, including resources of concern and their food resources.

Because the intensity and distribution of impacts caused by climate change are uncertain, monitoring will be an essential component of management. Gathering timely, relevant data on climate-induced habitat changes will facilitate adaptive management and allow managers to plan for future conditions. The following sections summarize some of the potential consequences of climate change on the refuge.

Sea Level Rise Associated with Climate Change

Global sea level rise has been occurring at least since the middle of the 19th Century. These observed increases in sea level are a result of ocean temperature increases (i.e., thermal expansion), as well as inputs from melting ice caps in Greenland and Antarctica. In the 20th Century, the rate was approximately 1.7 mm/year (.07 inches/year). Higher rates, up to 4 mm/year (0.16 inches/year) (Bindoff et al. 2007; Church et al. 2001; Meier et al. 2007; Carlson et al. 2008) are predicted for the 21st Century. Furthermore, local (i.e., relative) sea level rise along the Louisiana coast is much greater than the global mean, because of local, geological subsidence, which has been known for some time (Salinas et al. 1986). Relative sea level change rates near the refuge, as measured at Grand Isle, Louisiana, are close to 9 mm/yr. (0.36 inches/year) (NOAA 2010).

Much of Mandalay NWR lies at or very close to sea level. As sea levels rise, habitat conversion from freshwater to more saline conditions will occur. Storm surge events will reach higher elevations, inundating low-lying refuge lands with saltwater. Canals will serve as pathways for saltwater intrusion, hastening the habitat conversion process. Although these processes are not expected to significantly change management actions within the relatively short time frame of this HMP, they will certainly affect the long-term management of the refuge and dictate the range of options for habitat management. Actively working to prevent and reverse erosion of marsh and spoil banks (an action prescribed in this HMP) will prolong the life of the refuge's marshes, though no management actions can prevent the eventual conversion of the freshwater marsh to more saline environments, should current sea level trends continue. Closing canals can slow or prevent saltwater intrusion, but would interfere with access for Service personnel and the public, and thus is not prescribed in this HMP.

Effects of Climate Change on Tropical Cyclones

Tropical cyclones (i.e., tropical storms, hurricanes) are fueled by warm waters in the tropical oceans. Storms which affect the U.S. Gulf coast usually originate in the tropical North Atlantic Ocean and move westward steered by winds aloft. Recent research has found a strong correlation between surface water temperatures and the intensity of these storms. Warmer ocean temperatures are thus likely resulting in higher wind speeds in tropical cyclones. Interestingly, no increase in storm frequency has been detected (Elsner et al. 2008). It is likely that future large hurricanes, fueled by increasingly warmer waters, will affect the refuge.

Changes in Phenology and Species Distribution Due to Climate Change

Effects of climate change on species and biological communities are difficult to predict because interactions between future climate change effects and among species are unknown. However, in general it can be expected that warming temperatures, with concomitant decreases in the frequency and intensity of freezes, will result in pole-ward and elevation shifts of species either able to exploit new areas because of warming and/or unable to use their former ranges due to excessive heat. Migratory species can be expected (and have already been observed) to modify their migration timing in response to changes in temperature regimes. Similar shifts would likely occur as a result of changes in precipitation patterns (McCarty 2001; Parmesan & Yohe 2003; Root et al. 2003; Hannah et al. 2005; Parmesan 2006). A major concern for conservationists is that shifts in migration and species ranges will cause disconnects between coevolved species which depend on each other, disrupting, for example, specialist pollinator/plant interactions or predator/prey relationships. Such disruption could result in extirpation or extinction of some species and have cascading effects throughout ecosystems (Root et al. 2003).

III Resources of Concern

The Service is entrusted by Congress to conserve and protect "trust species," which are migratory birds and fish, federally listed threatened and endangered species, inter-jurisdictional fishes, and certain marine mammals. In addition to this congressional mandate, each refuge has one or more purposes for which it was established that guide its management goals and objectives. Refuges also support other elements of biological diversity including invertebrates, rare plants, unique natural communities, and ecological processes that contribute to biological diversity, integrity, and environmental health at the refuge, ecosystem, and broader scales (U.S. Fish and Wildlife Service 2011), (601 FW 3).

The HMP policy (620 FW 1) defines "resources of concern" as:

All plant and/or animal species, species groups, or communities specifically identified in refuge purpose(s); Refuge System mission; or international, national, regional, state, or ecosystem conservation plans or acts. For example, waterfowl and shorebirds are a resource of concern on refuges whose purpose is to protect migrating waterfowl and shorebirds. Federal or state threatened and endangered species on that same refuge are also a resource of concern under terms of the respective Endangered Species Acts.

IDENTIFICATION OF REFUGE RESOURCES OF CONCERN

In accordance with the purpose of Mandalay NWR and the priorities laid out in the refuge CCP, we selected four groups of animals as resources of concern: waterfowl, marsh birds, wading birds, and raptors. Each of these groups will be discussed below, with justifications for their selection, habitat requirements, and the potential contribution that Mandalay NWR can make to those habitat requirements. Also discussed below are two groups of birds which, though they are not the focus of management actions on the refuge, benefit from management on behalf of the resources of concern. These species groups with complementary habitat needs are neotropical songbirds and shorebirds.

WATERFOWL

Mandalay NWR provides high-quality habitat for wintering waterfowl, year-round resident species including wood duck and mottled duck, and black-bellied whistling-duck, a migratory species which breeds and winters on the refuge. Providing habitat for this group of species fulfills the refuge purpose and is a major focus of management at Mandalay NWR.

Wintering Waterfowl

Mandalay NWR is located at the southern end of the Mississippi Flyway (Figure 5), and provides important habitat for migrating ducks and geese which breed in the north-central section of the continent (Reinecke et al. 1989). The refuge attracts thousands of blue-winged teal (*Anas discors*), green winged teal (*Anas carolinensis*), American wigeon (*Anas americana*), ring-necked duck (*Aythya collaris*), lesser scaup (*Aythya affinis*), gadwall (*Anas strepera*), and northern pintail (*Anas acuta*).

Freshwater marsh habitat, including shallow open water which supports submersed and floating-leaved vegetation, is excellent foraging, loafing, and roosting habitat for wintering ducks. Management actions prescribed in this HMP are focused on maintaining and enhancing this habitat type over the next 15 years.

Resident/Breeding Waterfowl

Three species of waterfowl breed on Mandalay NWR: mottled duck, wood duck, and black-bellied whistling-duck. All three species are year-round residents. Mandalay NWR supports a resident population of wood ducks as well as providing winter habitat to migratory wood ducks which have bred further north (Dugger & Fredrickson 1992). Wood ducks nest in tree cavities throughout most of their range, and are dependent on flooded habitat with low cover (shrubs or emergent vegetation) for brood habitat. Wood duck populations are thought to be increasing or stable (NAWMP Committee 2004), although estimates are difficult because aerial census is not possible in wooded habitat. The refuge provides nest boxes to supplement natural cavities.

Black-bellied whistling-ducks are a neotropical species which has expanded its range in the past few decades and now breed and winter on Mandalay NWR. Like wood ducks, black-bellied whistling-ducks are primarily cavity nesters, although they have also been documented nesting on the ground (James & Thompson 2001).

Mottled ducks (*Anas fulvigula*) inhabit coastal marshes from Florida to Texas. Two subspecies are recognized: ssp. *fulvigula* in Florida and ssp. *maculosa* in Louisiana and Texas (Rorabaugh & Zwank 1983). Texas populations have declined in recent decades (1966-2002), but Louisiana populations apparently remained stable during that period (Wilson 2007). Recent survey data suggest that the Louisiana population of mottled ducks may be increasing (D. Breaux pers. comm.).

MARSH BIRDS

A suite of marsh birds, including 4 species in the family Rallidae, as well as pied-billed grebe, American bittern, and least bittern (Table 3), depend on the marsh habitats on Mandalay NWR and are a resource for which the refuge was created in 1996. These birds were selected as a resource of concern because they serve as focal resources for the marsh habitat which composes most of the refuge, and their conservation is a priority for refuge managers. Protecting habitat for these birds will improve biological integrity, diversity, and ecological health of the entire system (Kushlan et al. 2002).

Table 3. Marsh birds known from Mandalay NWR, with their conservation status (Hunter et al. 2006)

Species	Scientific Name	Tier[1]	Conservation Status (Action Level)[1]	Seasons of Occurrence in Terrebonne Parish[3]			
Podocipedidae				Sp	S	F	W
Pied-billed Grebe[2]	*Podilymbus podiceps*	Concern	Management Attention	c	o	c	a
Rallidae							
King Rail	*Rallus elegans*	Concern	Immediate Management	c	c	c	c

Species	Scientific Name	Tier[1]	Conservation Status (Action Level) [1]	Seasons of Occurrence in Terrebonne Parish[3]			
Common Gallinule[2]	*Gallinula galeata*	Local or Regional Interest	Planning and Responsibility	c	c	c	c
Purple Gallinule[2]	*Porphyrio martinica*	Concern	Immediate Management	u	c	u	
American Coot	*Fulica americana*	Additional Local or Regional Interest	Management Attention	a	c	a	a
Ardeidae							
American Bittern	*Botaurus lentiginosus*	Regional Concern Only	Management Attention	u	u	c	c
Least Bittern[2]	*Ixobrychus exilis*	Concern	Management Attention	c	c	c	r

[1] For more information, see Hunter et al. (2006).
[2] Breeds on refuge
[3] a=abundant; c=common; u=uncommon; r=rare; e=erratic; o=occasional (Terrebonne Bird Club Field Checklist; copy available at refuge office).

COLONIAL NESTING WADING BIRDS

Mandalay NWR provides habitat for colonial waterbirds throughout the year. Twelve species of colonial wading birds are documented to breed on the refuge (USFWS 2007, Table 4). (Kushlan et al. 2002) ranked North American waterbirds in terms of "Category of Concern," which they define as a measure of the risk of serious population loss. Providing habitat for these birds is a priority for the refuge.

Table 4. Colonial waterbird species known from Mandalay NWR

Common Name	Scientific Name	Winter	Summer	Breeds On Refuge	Conservation Status*
Ardeidae					
Great Blue Heron	*Ardea herodias*	x	x	x	Not currently at risk
Great Egret	*Ardea alba*	x	x	x	Not currently at risk
Snowy Egret	*Egretta thula*	x	x	x	High risk
Little Blue Heron	*Egretta caerulea*	x	x	x	High risk

Common Name	Scientific Name	Winter	Summer	Breeds On Refuge	Conservation Status*
Tricolored Heron	*Egretta tricolor*	x	x	x	High risk
Cattle Egret	*Bubulcus ibis*	x	x	x	Not currently at risk
Black-crowned Night-Heron	*Nycticorax nycticorax*	x	x	x	Moderate risk
Yellow-crowned Night-Heron	*Nyctanassa violacea*	x	x	x	Moderate risk
Green Heron	*Butorides virescens*	x	x	x	Low risk
Threshkiornithidae					
Roseate Spoonbill	*Plantalea ajaja*	x	x	x	Moderate risk
White Ibis	*Eudocimus albus*	x	x	x	Moderate risk
White-faced Ibis	*Plegadis chihi*	x	x	x	Low risk

** (Kushlan et al. 2002)*

Two rookery areas are mapped on Mandalay NWR (Figure 7), although use has declined or discontinued as of this writing (May 2012). Others may exist; colonial waterbirds shift locations every few years.

RAPTORS

Raptors were chosen as a resource of concern because of their importance to the marsh ecosystem as predators and because they function as indicator species for high-quality marsh, cypress-tupelo swamp, and open water habitat. A major component of habitat management on Mandalay NWR is maintaining open water areas, including natural ponds as well as canals. Raptors which regularly use the refuge include black vulture, turkey vulture, osprey, swallow-tailed kite, Mississippi kite, sharp-shinned hawk, Cooper's hawk, northern harrier, red-shouldered hawk, red-tailed hawk, bald eagle, and American kestrel. Of particular interest and importance to the refuge are the bald eagle and osprey because of their use or potential use of breeding habitat on the refuge and the northern harrier due to its dependence on the refuge's marshes during the winter. As of the 2012 breeding season, a pair of bald eagles has nested on the refuge's Ridge Canal unit for 12 consecutive seasons, fledging one or two young each year (U.S. Fish and Wildlife Service 2009). No osprey nests are known to be on Mandalay NWR at the time of this writing (2012), but ospreys nest in nearby areas and probably use the refuge for foraging.

HABITAT REQUIREMENTS OF RESOURCES OF CONCERN

WATERFOWL

Wintering Waterfowl

Most North American waterfowl species migrate long distances to satisfy their annual cyclic habitat needs. Habitat requirements vary with the breeding cycle, and habitats all along the flyways are critical links in a chain which sustains waterfowl populations. Strategic conservation of habitat, including planning, protection, and management, is the primary way that humans can ensure healthy populations of waterfowl (or any wildlife) (Reinecke et al. 1989).

During winter, dabbling ducks prefer shallow wetland habitat that is approximately evenly divided between open water areas and emergent vegetation, with large amounts of edge. Waterfowl use plant- and animal-derived foods found in marshes and moist-soil areas (either natural or managed). These include roots, tubers, seeds, and invertebrates such as snails, insects, and crustaceans (Kaminski et al. 2003; Heitmeyer 1988; Heitmeyer 2006). Besides feeding, waterfowl use marshes and moist-soil areas for loafing, pair bonding, and thermal cover (Reinecke et al. 1989). Mallards, gadwall, teal, American wigeon, shovelers, and geese are among the species which use these areas on Mandalay NWR.

Protecting waterfowl from disturbance caused by humans and other predators as well as noise from boats and guns is crucial for good wintering habitat. Ducks and geese have significant energetic and nutritional requirements to support moults and other biological processes and to maintain them through cold weather periods. Disturbance-free habitat enables them to build energy reserves for spring migration and reproduction (Reinecke et al. 1989; Strickland et al. 2009). If waterfowl are disturbed on wintering habitat, it can interfere with feeding and resting and cause them not to gain sufficient weight to sustain them through the year (Henry 1980; Heitmeyer & Raveling 1988; Kahl 1991. In a study in Louisiana, even increased foraging time by gadwalls was insufficient to overcome the effects of disturbance (Paulus 1984).

Resident/Breeding Waterfowl

Wood duck

Wood ducks spend their entire life cycle in and around forested wetlands (U.S. Fish and Wildlife Service 2001). Wood ducks nest in tree cavities within 1 km (0.6 mile) (preferably 500 m (1,640 feet or less) of water; longer distances are associated with lower brood survival (USFWS 2001). Flooded wood duck habitat is ideally shallow with 50-75 percent cover provided by shrubs or emergent vegetation (Dugger & Fredrickson 2007; U.S. Fish and Wildlife Service 2001). Nest boxes are readily used, and single, hidden, well-spaced boxes are best (Hepp & Bellrose 1995). Wood ducks forage mostly in flooded timber, and will only use agricultural habitat if forest is not available. Since wood ducks rarely dive or feed from the bottom, they require shallow (< 8 inches) water for feeding (Dugger & Fredrickson 1992).

Wood ducks begin nesting as early as late January on the Gulf coast, and the incubation period is 30 days or less (Dugger & Fredrickson 1992). They are omnivorous, but their proportion of animal and plant food sources changes through the year reflecting availability of food and nutritional requirements of breeding, molting, and wintering. During the breeding season, foraging habitat must provide energy and protein for the hen during egg-laying and for the developing ducklings. Hens eat mainly (80 percent) animal food sources during egg-laying, concentrating on invertebrates that are available on the surface of the water and on riparian areas. Drakes increase their intake of animal sources during the

spring as well; invertebrates compose up to 1/3 of their diet during this time. During incubation, hens shift to high-energy seeds to meet the metabolic requirements of incubation. Ducklings consume mostly invertebrates and small fish until they are 6 weeks old, and then shift to mostly plant sources as they mature (U.S. Geological Survey 2006). During the winter, diet for both sex shifts to nearly 100 percent plant sources, and acorns may account for up to 75 percent of the total intake.

Mottled duck

Mottled ducks are dabbling ducks closely related to mallards. They have very similar wintering habitat requirements to other members of their genus. However, unlike most North American *Anas* species, they are year-round residents of the Gulf coast. They therefore require habitat for breeding, feeding, loafing, and other activities during the spring, summer, and fall, as well as during the winter. Mottled ducks generally prefer fresh to brackish marsh for feeding and loafing, although they will use rice fields and rarely flooded prairie sites as well (Rorabaugh & Zwank 1083). They primarily consume plant material as adults, grazing in shallow water for seeds or in deeper water on submerged aquatic plants (Paulus 1984), but consume more animal material as ducklings when additional protein is required (Rorabaugh & Zwank 1983). Over the year, these birds use a succession of habitat types for different activities. During pair bonding in early winter, mottled ducks preferentially use small ponds within the coastal marsh for attracting mates and pairing (Haukos et al. 2010). Then, hens select nesting habitat which has quite different characteristics, and after hatching, they seek out brood habitat with yet another set of characteristics (Rorabaugh & Zwank 1983). Post-breeding habitat differs from all of the habitats used during the breeding season. Although all of these habitat types are found within healthy coastal marsh, it is important for managers to understand how specific habitat requirements change over the year.

Mottled ducks primarily feed (as adults) on plant materials in shallow (≤30 cm/1 foot) water. They spend most of their time in or near emergent, graminoid marsh habitat. During the post-breeding molt, when they are flightless for a month, they prefer larger bodies of water with shallow beds of submerged aquatic vegetation and escape cover on the margins (Rorabaugh (Rorabaugh & Zwank 1983). Salinities in these habitats can vary from fresh to brackish or saline.

Sometime in late fall or early winter, pair bonding begins for this species. Drakes occupy and defend small (0.02-0.15 ha/0.05-0.4 ac, ~1 m/3 feet deep) ponds surrounded by marsh habitat (Haukos et al. 2010), and by December, 90 percent of them are paired (Paulus 1984). In a recent study in southeast Texas, mottled ducks used ponds with salinities ranging from fresh to saline; however, they preferentially selected shallow, fresh ponds (≤ 2 ppt salinity) and ones that were surrounded by marsh vegetation that had been grazed recently. They avoided ponds surrounded by recently burned marsh vegetation (Haukos et al. 2010).

Mottled ducks begin nesting in February, and nesting continues through August (Rorabaugh & Zwank 1983; Walters 2000). They prefer a high land/water ratio for nesting habitat, and prefer prairie vegetation over marsh or woody cover (Walters 2000). Nests are often found against clumps of grass or small shrubs within 150 m (~500 feet) of water. Nesting mottled ducks will generally avoid areas which are wet or which have dense shrubs or trees (Rorabaugh & Zwank 1983).

Hens will select brood habitat which, unlike breeding habitat, has a low land/water ratio but which has abundant edge and cover for ducklings. Ducklings are less efficient feeders than adults, so hens will preferentially bring broods to areas of abundant food supply (Afton & Paulus 1992) and may travel several kilometers (1 km = 0.6 miles) from the nest to reach favorable brood-rearing habitat (Paulus

1984). Young ducklings (<4 weeks) require a high proportion of their diet to be of animal origin, chiefly small fish, mollusks, insects, and amphipods (Rorabaugh & Zwank 1983).

Black-bellied whistling-duck

Black-bellied whistling-ducks nest in shallow freshwater wetlands, either with emergent or floating vegetation, or without vegetation. Brood habitat is similar to nesting habitat, with emergent vegetation interspersed with open water. Nests are usually in tree cavities, but ground nests have been observed (Dale & Thompson 2001). In south Texas, black-bellied whistling-ducks nested most frequently in live oak (*Quercus fusiformis*) and Texas ebony (*Pithecellobium flexicaule*), though nests in other species, including elm (*Ulmus spp.*) and willow (*Salix spp.*) were also recorded (Delnicki & Bolen 1975). Cavities in live and dead trees were used, and averaged 1-2 m above the ground. In the same study, the authors found that 57 percent of the nests were more than 200 m from water, and 33 percent were more than 500 m from water. A few nests were more than 1 km from water. The authors speculated that distance from water, although apparently not a critical nest selection criterion for the bird may have an influence on brood survival, as it does for other cavity-nesting ducks. Cavities observed by (Delnicki & Bolen 1975) averaged 17 cm wide and 31 cm high, and the smallest observed opening was 10 x 12 cm. Interior floor space averaged 664 cm^2.

Black-bellied whistling-ducks readily use nest boxes. In a 12-year nest-box study in south Texas, nest success for incubated nests (which composed 37 percent of all nests) was 75 percent (McCamant & Bolen 1979). All nest boxes in their study were placed within 100 m of water, and within this narrow range of distance, no effect of distance to water on box utilization was noted. The authors did not report brood survival data for these nests.

Diet for this species is primarily (92 percent) plant-based during the breeding season. Agricultural grains are eaten readily, and wild seeds such as smartweed (*Polygonum* spp.), barnyard grasses (*Echinochloa* spp.), Mexican sprangletop (*Leptochloa uninerva*), flatsedges (*Cyperus* spp.), amaranths (*Amaranthus* spp.), dock (*Rumex* spp.), bindweed (*Convolvulus* spp.), nightshades (*Solanum* spp.), and sunflowers (*Helianthus* spp.) are used as well. Refuge surveys have identified seeds and tubers of *Hydrilla verticillata*, a common exotic submersed weed (Langeland 1996) on Mandalay, in the crops of black-bellied whistling-ducks on the refuge. Animal matter, mostly molluscs and arthropods, make up the balance of the diet of black-bellied whistling-ducks (Dale & Thompson 2001).

MARSH BIRDS

As with many other groups of birds, the variables that control habitat selection and quality are many and complex for marsh birds. At small scales, food availability, cover, nest material, protection from predators and weather, presence of open water, water depth, and type, height and density of vegetation, all influence habitat selection and use by these birds (Riffell, Keas & Burton 2003; Osnas 2003; Lor & Malecki 2006; Johnson & Dinsmore 1986). On landscape scales, the area and distribution of suitable habitat patches are important determinants in use by certain marsh birds, while others appear not to be affected by these variables ((Brown & Dinsmore 1986; Benoit & Askins 2002; Fairbairn & Dinsmore 2001). A general understanding of these variables and how they influence habitat quality and avian species richness on the refuge is important for management decisions. Two habitat requirements are shared by most or all of the species which use Mandalay NWR: the presence of emergent marsh vegetation, mostly graminoid, and the presence of open water in various proportions to the marsh cover. Specific requirements of the seven species of marsh birds which breed or winter on the refuge are presented in Table 5.

Table 5. Habitat requirements and preferences of seven marsh bird species which occur on Mandalay NWR

SPECIES	HABITAT COMPONENT REQUIREMENTS ON MANDALAY NWR						
	Emergent graminoid marsh	**Preferred or associated plant species**	**Open Water**	**Salinity**	**Water Depth**	**Other Requirements or Preferences**	**Large Scale Requirements**
Pied-billed Grebe* (Muller & Storer 1999)	Marsh nest requires ≥ 10 cm^2 of stem basal area per m^2 of marsh		Breeds on ponds >0.2 ha	Fresh to Brackish	>0.25 m	Nest on floating platform among tall emergent vegetation in open water.	Area-dependent breeder (Naugle et al. 2001); Nests much more frequently in marsh habitat patches ≥5ha (Brown & Dinsmore 1986)
King Rail* (Poole et al. 2005)	Yes	*Typha* spp., *Schoenoplectus olneyi, Spartina cynosuroides, Zizaniopsis miliacea, Panicum hemitomon, Cladium jamaicense, Echinochloa* spp., *Polygonum* spp.		Fresh to Brackish		High marsh with sparse woody vegetation	
Common Gallinule* (Bannor & Kiviat 2002)	Yes	*Typha* spp., *Schoenoplectus* spp., *Panicum hemitomon, Sagittaria lancifolia, Nuphar lutea, Nymphaea odorata, Nelumbo lutea, Ceratophyllum demersum, Potamogeton* spp., *Hydrilla verticillata*	Prefers at least 50% open water	Fresh to slightly Brackish	Prefers water 15-120 cm deep	Uses flotant marsh for resting and breeding (Bell 1976); prefers dense submerged and floating-leaved vegetation	Uses a variety of small, isolated, or polluted habitats for breeding (Bannor & Kiviat 2002); breeds successfully in rice fields in southwestern Louisiana (Helm, Pashley & Zwank 1987)

SPECIES	HABITAT COMPONENT REQUIREMENTS ON MANDALAY NWR						
	Emergent graminoid marsh	**Preferred or associated plant species**	**Open Water**	**Salinity**	**Water Depth**	**Other Requirements or Preferences**	**Large Scale Requirements**
Purple Gallinule* (West & Hess 2002).	Yes	*Brasenia schreberi, Nelumbo lutea, Nuphar lutea, Nymphaea odorata, Pontederia cordata, Sagittaria* spp., *Typha* spp., *Panicum hemitomon, Schoenoplectus* spp., *Zizaniopsis miliacea, Juncus* spp., *Lemna* spp., *Eichhornia crassipes, Potamogeton* spp., *Ceratophyllum demersum, Hydrilla verticillata, Cephalanthus occidentalis*	Prefers <25% open water	0-5.0 ppt	deep: 0.25-1.0m	Walks on floating or emergent vegetation to feed on invertebrates and flowers; constructs nest over water (Helm, Pashley & Zwank 1987)	
American Coot* (Brisbin and Mowbray 2002)	Yes		Yes; uses bays and ponds, esp. in winter	Fresh to Brackish	Deepwater often used		
American Bittern (Lowther et al. 2009)	Yes	Uses a wide variety of wetland habitats during wintering, including fresh and brackish coastal marsh.		Fresh to Brackish	Shallow water, may forage in terrestrial grasslands		

SPECIES	HABITAT COMPONENT REQUIREMENTS ON MANDALAY NWR						
	Emergent graminoid marsh	**Preferred or associated plant species**	**Open Water**	**Salinity**	**Water Depth**	**Other Requirements or Preferences**	**Large Scale Requirements**
Least Bittern* (Poole et al. 2009)	Yes	*Typha* spp., *Carex* spp., *Schoenoplectus* spp., *Sagittaria* spp.	Yes, mixed with marsh and woody veg.	Fresh to Brackish	≤0.5m	Clumps of woody vegetation	Nests much more frequently in marsh habitat patches ≥5ha (Brown and Dinsmore 1986)

**Species breeds or may breed on Mandalay NWR.*

COLONIAL NESTING WADING BIRDS

Colonial waterbirds are a taxonomically and ecologically diverse group. However, the suite of species can be considered as a single resource of concern because their general habitat requirements are similar, and management actions taken to benefit one species will generally benefit all. (Hafner 1997) divides the general habitat requirements of these wading birds into three components: colony site requirements (rookeries), feeding habitat during breeding season, and feeding habitat during non-breeding season.

Nesting sites, or rookeries, must provide the nesting birds with nest substrates, protection from weather, and security from predation. Rookeries where ground-nesting takes place are therefore usually surrounded by water, but can be protected by dense vegetation instead. In the absence of these components, most colonial wading birds require tall woody vegetation as nest substrate in order to secure the nest from ground-based predators (Hafner 1997). Great blue herons prefer nest sites 7-10 m high in trees, while black-crowned night herons, snowy egrets, little blue herons, and great egrets tend to nest on islands in shrubby vegetation (Habitat Objectives Workgroup 1991). Protection from wind, rain, and flooding must be adequate for successful nesting to occur. Rookeries also must have nearby food and nest material resources adequate for the number of birds using the rookery (Hafner 1997).

Feeding habitat during the breeding season must provide sustenance for adults as well as chicks, and must be located within some maximum radius of the rookery that allows foraging adults to efficiently capture and transport food to the nest (Gibbs 1991; Hafner 1997). The size of the rookery (number of nesting pairs) is often limited by availability of suitable feeding habitat within this radius (Hafner 1997). This has been shown for great blue herons (Gibbs 1991) and black-crowned night herons (Fasola & Barbieri 1978) among other species. Fasola and Barbieri (1978) reported that heron rookeries in Italy were spatially arranged to efficiently divide up the available feeding habitat. Gibbs (1991) likewise reported that great blue heron rookeries in Maine were located near optimum locations relative to dispersed, disjunct wetland feeding habitat. Birds are able to exploit different prey and feeding habitats at different times of the day when prey are most available; therefore, habitat diversity within the available radius is an important factor as well (Hafner 1997).

On Mandalay NWR, two rookery sites are mapped (Figure 7); it is possible that others exist. Use of the two mapped rookeries on Mandalay NWR has ceased or declined in recent years. Use of rookery sites is typically ephemeral; a site will be used for several years and then abandoned (Green, Leberg & Luent 2010). It is therefore important to protect all known rookery areas when management activities are carried out, and to strategically select locations for future rookeries where woody vegetation is allowed to develop.

Non-breeding season feeding habitat requirements for Gulf coast wading birds are similar to those during the breeding season, except that white ibises, which forage in saltwater during the non-breeding season, require freshwater prey for feeding nestlings during the breeding season (Chavez-Ramirez & Slack 1995). Types of habitat used during the non-breeding season include shallow open water and water margins. Vegetated areas are much less likely to be utilized by wading birds on the Gulf coast (Chavez-Ramirez & Slack 1995).

Some researchers have reported that multi-species populations of wading birds partition feeding habitat use. Partitioning can occur by water depth, with longer-legged birds able to forage in deeper water (Hafner 1997), by time of day (Post 2008), or size/configuration of open water area (Chavez-Ramirez & Slack 1995). Recent work has questioned the idea that resource partitioning occurs among diurnal wading birds, especially when food resources are not limiting (Post 2008).

RAPTORS

Raptors (including New World vultures) use all of the habitats of Mandalay NWR (Table 6). For the three focal species within this group, baldcypress-tupelogum swamp, freshwater marsh, and open water habitats are particularly important.

Table 6. General habitat use of 12 raptor species on Mandalay NWR

Common Name	Habitat Use on Mandalay National Wildlife Refuge			
	Bottomland Hardwood Forest	Baldcypress – Tupelogum Swamp	Freshwater Marsh	Open Water
Black Vulture	x			
Turkey Vulture	x			
Osprey		x		X
Swallow-tailed Kite	x			
Mississippi Kite	x			
Sharp-shinned Hawk	x			
Cooper's Hawk	x			
Northern Harrier			x	
Red-shouldered Hawk	x	x	x	
Red-tailed Hawk				
Bald Eagle	x	x		X
American Kestrel	x			

Bald eagle

Bald eagles nest in mature forest habitat, adjacent to, or within 2 km of, water (Buehler 2000). Shallow water is preferred for foraging (Livingston et al. 1990) and both marine and freshwater areas are used (Buehler 2000). Numerous authors have noted that bald eagles tend to avoid human disturbance, generally selecting habitat at least 500 m from human structures and activity (Andrew & Mosher 1982; Livingston et al. 1990; Wood, Edwards & Collopy 1989; Buehler 2000).

In areas where trees are available, nest sites are generally in super-emergent trees with limbs capable of supporting the large nest. Nests are often used for several years by the same pair, and nest maintenance proceeds year-round in southern latitudes (Buehler 2000). In Florida, bald eagles in pine-dominated habitats selected mostly living pine trees which were not significantly taller than surrounding trees (Wood, Edwards & Collopy 1989). In Maryland, bald eagles selected pines or hardwoods in relatively open habitat compared with random points, but vegetation density was positively related to nest success (Andrew & Mosher 1982). Likewise, the authors reported that all nests averaged closer to water than random points (637 m vs. 1,128 m), but among all counted nest sites, proximity to water was significantly negatively related to nest success. They suggested that this paradox may be explained by the fact that denser vegetation further from water had less human disturbance, which is known to negatively affect nest success. In a study in southeastern Louisiana, most bald eagle nests were in dominant or co-dominant baldcypress trees, with swamp, open water, and/or marsh habitat in close proximity (Harris, Zwank & Dugoni 1987).

Bald eagles winter in a broad range of habitats, but most are characterized by proximity to water with high concentrations of prey, tall trees for perching, and low levels of human activity. Roosting trees generally offer some protection from the elements, but can be evergreen or deciduous. Open crowns are required for accessibility (Buehler 2000).

Osprey

Osprey are year-round residents along the Gulf coast, including Terrebonne Parish, although through most of its range the species is migratory, breeding in the northern United States and Canada, and wintering in Texas, Mexico, and Cuba. Breeding habitats are varied across the range, but features common to all include adequate fish populations in shallow water (0.5-2m deep), either fresh or marine, within 10-20 km of the nest site, and a secure, open nest site, which can be a tall tree, predator-free island, large rock or cliff, or an artificial structure either designed for nesting or “repurposed” by the birds (e.g., power line or cell tower) (Poole, Bierregaard & Martell 2002). Like breeding habitat, preferred wintering habitat for migratory ospreys includes shallow water, fresh to marine, with adequate prey (Poole, Bierregaard & Martell 2002). Few data are apparently available specifically regarding the resident osprey population on the Gulf coast; however, it can be assumed that general habitat requirements are similar.

Northern harrier

Northern harriers winter across the southern half of North America and along the Pacific Coast, and use a wide variety of habitats from wetlands to deserts (Smith et al. 2011). On Mandalay NWR, they use the refuge’s extensive freshwater marsh for hunting. In a freshwater marsh in Florida, northern harriers subsisted on cotton rats and other small prey, including birds and snakes, while in a salt marsh in South Carolina they depended exclusively on birds (Collopy & Bildstein 1987). The birds they observed exhibited different capture techniques in the different habitats, indicating that the species is adaptable to a wide range of conditions and prey bases. The authors speculated that

such behavioral plasticity may account for the species' wide range. It is likely that in Mandalay NWR's freshwater marshes, which are similar to freshwater marsh habitat described by Collopy and Bildstein, northern harriers have a similar prey base.

POTENTIAL REFUGE CONTRIBUTION TO HABITAT REQUIREMENTS OF RESOURCES OF CONCERN

WATERFOWL

Nearly all of the habitats on Mandalay NWR are used by waterfowl during some or all of the year. The refuge provides 3,700 acres of fresh marsh and shallow open water with submerged aquatic vegetation, 175 acres of bottomland hardwoods and 75 acres of cypress-tupelo swamp. Approximately 100 wood ducks winter on Mandalay NWR. A few breeding pairs are supported each year through a small nest box program, and up to 100 wood ducks utilize the Hanson Unit and Lake Hatch for brooding and molting during late spring and summer.

MARSH BIRDS

Mandalay NWR provides approximately 2,900 acres of fresh marsh, as well as about 800 acres of open water habitat used by secretive marsh birds and their allies.

COLONIAL-NESTING WATERBIRDS

The refuge currently has two mapped rookeries (Figure 7) totaling 12 acres. The 3,700 acres of freshwater marsh and shallow open water and 75 acres of cypress-tupelo swamp provide foraging habitat for these birds, while other wooded sites on the refuge may be suitable for rookeries.

RAPTORS

Mandalay NWR provides 3,700 acres of marsh and open water habitat, as well as 250 acres of forested wetland, all of which are used by bald eagles, osprey, northern harriers, and other raptors. Management actions detailed in this HMP are focused on maintaining habitat quality of these essential habitat components, specifically shallow open water with abundant fish populations and mature forested wetland habitat with old, emergent tree crowns.

SPECIES WITH COMPLEMENTARY HABITAT REQUIREMENTS

Habitat objectives and strategies will be established based primarily on the habitat needs of the above-identified resources of concern. However, an ecosystem management approach to habitat management will result in overall improvement in the health and function of the ecosystem on the refuge, benefitting many other species, including those for which the Service has responsibility under Federal law. The following species groups are listed in the CCP (U.S. Fish and Wildlife Service 2009) as priorities for the refuge, have habitat needs that are similar to or compatible with those of the resources of concern, and are therefore expected to benefit from management designed to meet the needs of the resources of concern. However, no management actions are targeted specifically at these species groups.

NEOTROPICAL SONGBIRDS

A number of neotropical songbirds use the forested wetland habitats on Mandalay NWR for breeding; in addition, the refuge provides important stopover habitat for migratory birds in the spring and fall. Management actions described in this HMP will benefit these birds by maintaining and enhancing the quality of those habitats over time.

SHOREBIRDS

The refuge provides important stopover habitat for migrating shorebirds. At low tide, particularly when tides are very low due to north winds in the fall and early spring, marsh bottom areas are dewatered and function as mud flat habitat. These habitats are important to shorebirds for stopover and feeding. Actions described in this HMP will maintain open water areas within the marsh, which will continue to function as mud flats at low tide. In addition, black-necked stilts are residents on the refuge year-round and use the marsh habitat to meet all of their requirements for breeding and overwintering.

RECONCILING CONFLICTING HABITAT NEEDS

Habitat requirements for the refuge's four resources of concern are largely compatible. All of the birds for which the refuge is managed benefit from healthy freshwater marsh, and those which require or use forested wetland habitat (wood duck, black-bellied whistling-duck, bald eagle, osprey, wading birds) will benefit from generally healthy swamps and bottomland hardwood forests. Management actions prescribed in this HMP are intended to improve the overall health of the natural systems on Mandalay NWR. This HMP does not anticipate the conversion of habitat of one type to that of another (other than small-scale restoration projects); thus, the resources of concern face only natural limits on their habitat size based on available substrates.

IV Habitat Management Goals and Objectives

The following habitat management and wildlife population management goals and objectives were developed for the CCP (U.S. Fish and Wildlife Service 2009) and form the basis of this HMP:

GOAL 1. Identify, conserve, manage, and restore populations of native fish and wildlife species representative of the Barataria-Terrebonne Basin, with emphasis on migratory birds and threatened and endangered species.

Objective 1.1: Manage and protect migratory bird populations.

Strategies:

- Maintain wood duck boxes.
- Survey migratory wintering waterfowl and other species such as mottled ducks and black-bellied whistling-ducks to determine and record trends in waterfowl distribution.
- Band wood ducks, mottled ducks, and black-bellied whistling-ducks when the opportunity arises.
- Establish a partnership between the refuge and the research community to promote monitoring and researching to determine the most effective methods for waterfowl management.
- Modify management actions to improve waterfowl and other wildlife habitat.
- Conduct wading bird rookery surveys.
- Conduct bald eagle survey to attain use of refuge and monitor nest site off of Ridge Canal.
- Protect existing cypress stands on Mandalay NWR, located primarily within swamp habitat adjacent to the natural ridge.
- Protect any nesting bald eagles from disturbance that could lead to nest abandonment.
- Conduct marsh bird survey to attain use of marsh and open water habitats.
- Explore possibility of conducting migratory songbird surveys to attain use of marsh and forested wetland areas by nongame migratory songbirds.

Objective 1.2: Manage and protect threatened and endangered species through implementation of recovery plans.

Strategy:

- Monitor any subsequent use of the refuge by migrating endangered species.

Objective 1.3: Monitor species of concern, targeted species, and species of federal responsibility in order to assess management goals.

Strategies:

- Conduct alligator surveys and harvest program (refer to Mandalay NWR alligator and furbearer plan).
- Continue to participate in the nutria control program (refer to Mandalay NWR alligator and furbearer plan).
- Continue feral hog control (refer to Mandalay NWR hunt plan).

Objective 1.4: Monitor resident and other species utilizing habitat on the refuge.

Strategies:

- Conduct forage surveys for white-tailed deer, herd density (browse surveys), and monitor harvest.
- Explore possibility of surveys for squirrel and rabbit abundance.
- Survey densities of other fur-bearer species using habitat on the refuge.

Objective 1.5: Monitor fish and shellfish habitat on the refuge.

Strategies:

- Monitor fish and shellfish species present on refuge via coordination with LDWF's Wildlife and Fisheries Inland and Marine Fish Divisions and report all fish kills.
- Continue correspondence with local fishermen and sportsmen to assess species in daily catch.

GOAL 2. To restore, improve, and maintain a mosaic of wetland habitats native to the Terrebonne Basin in order to ensure healthy and viable plant and animal communities, with an emphasis on migratory bird species.

Objective 2.1: Manage, maintain, and improve when possible fresh and intermediate marsh and other aquatic habitats for refuge resources.

Strategies:

- Monitor impacts of public use on habitat.
- Control invasive plant species and invasive exotic mammals (refer to Mandalay NWR Hunt Plan and furbearer trapping plan)
- Erosion control along the GIWW and other shorelines, placement of hard structures along the GIWW, and restoration of the GIWW bank line.
- Maintain lakes and ponds.
- Maintain and increase production of fish and wildlife species when possible.
- Creation of flotant marsh via cooperation with research projects, state and federal agencies, and coastal restoration grants.
- Structural hydrologic management via completion of proposed Hanson Unit Marsh project and replacement of water control structure on Ridge Canal.
- Continuously maintain marsh restoration and management project proposals on file and search for funding sources/partners to assist in implementation, and seek new funding for future enhancement projects.
- Develop an HMP by 2013.

Objective 2.2: Manage, maintain, and enhance when possible bottomland hardwood and cypress/tupelo swamp habitats and associated ridges and spoil banks for refuge resources.

Strategies:

- Stabilize shorelines via cooperation with research projects, state and federal agencies, and coastal restoration grants.
- Plant hardwood species when opportunity arises.
- Develop an HMP by 2013.

Objective 2.3: Support partnerships to protect natural habitats of the Terrebonne Basin.

Strategies:

- Continue cooperation with Terrebonne Parish and USDA Natural Resources Conservation Service with marsh grass plantings and Christmas tree cradles on the refuge.
- Continue to cooperate with Louisiana Department of Wildlife and Fisheries and the TE41 bank stabilization project on the refuge.
- Promote grass planting efforts to local community and school groups.

We have selected the following objectives, organized by habitat type, to address the habitat management-related goals and objectives in the refuge CCP. Each objective has an explicit reference to one or more habitat management-related CCP objectives.

FRESHWATER MARSH AND SHALLOW OPEN WATER

Emergent and flotant marsh and shallow lakes and ponds dominated by floating-leaved and submersed aquatic vegetation compose the bulk of the acreage on Mandalay NWR and represent the refuge's most important contribution to its resources of concern and to conservation in the Barataria-Terrebonne Basin. These habitats are important for resident and wintering waterfowl, wading birds, and marsh birds, as well as to other species which use the refuge including shorebirds, raptors, and the refuge's fisheries resources. Although managers have little control over water levels on the refuge, management actions can be taken which will maintain and improve these habitats over the life span of this HMP.

OBJECTIVE 1.1: FRESHWATER MARSH HABITAT MANAGEMENT

Each year through the end of the planning period for this HMP, restore and maintain the refuge's 3,700 acres of freshwater marsh and shallow open water habitats as follows:

- Marsh is approximately 50 percent emergent vegetation and 50 percent open water, with open water portions dominated by native floating-leaved and/or submersed aquatic vegetation;
- Open-water ponds and lakes are substantially free of floating mats of exotic invasive weeds (i.e., exotic floating mats cover less than 5 percent of the surface of Hanson Unit 1 and Lake Hatch Unit 2 at all times);
- Marsh vegetation loss from nutria and hogs is negligible;
- Loss of marsh habitat from erosion is halted by 2020.

Rationale: All of the refuge's resources of concern depend on marsh and open water habitats. Major threats to the continued high quality of these habitats are conversion of marsh to open water by erosion at the margins of artificial waterways, particularly the GIWW and invasive plants. Invasive plants displace more desirable components of habitat and in some cases impede access for managers and

refuge visitors. On Mandalay NWR, open water areas are susceptible to invasion by exotic floating plants which form impenetrable mats of vegetation. These mats are composed of salvinia, water hyacinth, and Cuban bulrush, as well as other plants which colonize the mats, including native species such as pennywort (*Hydrocotyle ranunculoides*) and maidencane (*Panicum hemitomon*). Floating mats of this type impede traffic in the lakes and shade out rooted aquatic species which are more valuable for wildlife. When the mats die back in the winter, they can cause anoxic conditions in the water column as they sink and decompose. Feasible management actions exist which will substantially mitigate these threats on the refuge.

Resources of Concern: Waterfowl, marsh birds, colonial wading birds

CCP Objective: 2.1

Adaptive Management Monitoring Elements:

Primary Habitat Response Variables	**Probable Assessment Methods**
▪ Cover of emergent marsh vegetation ▪ Cover of exotic floating mats	▪ Remote sensing, field surveys
Primary Wildlife Response Variables	**Probable Assessment Methods**
▪ Use by ROC	▪ Surveys

HABITAT MANAGEMENT OBJECTIVE 1.2: FRESHWATER MARSH RESTORATION

Working with partners, every 5 years over the planning period covered by this HMP, as funding is available, restore up to 100 acres of rooted emergent or flotant marsh on Mandalay NWR by planting, deposition of dedicated or beneficial dredge material, construction of organic fences (Christmas tree cradles), and/or installation of hardened structures along shorelines.

Rationale: Areas of freshwater marsh on the refuge have been damaged or lost to the effects of oil and gas extraction activities, hurricanes, and erosion from the GIWW. As these areas are reclaimed, restoration of native marsh vegetation will be necessary to stabilize substrate and consolidate gains in marsh habitat acreage. Marsh planting, either in conjunction with application of dredged material or on areas where sediment is still in place, is a well-understood technology (U.S. Environmental Protection Agency 1989) which has been used for decades on the Gulf coast and is used by the Service on other coastal refuges in Louisiana. Funding for marsh restoration initiatives is available.

Resources of Concern: Waterfowl, marsh birds, colonial wading birds

CCP Objectives: 2.1, 2.3

Adaptive Management Monitoring Elements:

Primary Habitat Response Variables	Probable Assessment Methods
▪ Presence of native marsh vegetation	▪ Remote sensing, periodic inspection
Primary Wildlife Response Variables	**Probable Assessment Methods**
▪ Use by ROC	▪ Surveys

FORESTED WETLANDS

The forested wetlands on Mandalay NWR, though a small portion of the refuge, provide an outsized contribution to refuge habitat diversity. Regionally, bottomland hardwoods and swamps are rare due to agricultural and urban competition for those environments and past (as well as possible future) exploitation of forest resources. Providing them on the refuge creates a habitat island and refugium for species which depend on them.

HABITAT MANAGEMENT OBJECTIVE 2.1: FORESTED WETLAND MANAGEMENT

As funding becomes available, during the planning period covered by this HMP, protect, manage, and restore 250 acres of bottomland hardwood forest and cypress-tupelo swamp (including hardwoods on approximately 103 acres of spoil banks along dredged canals) on Mandalay NWR so that:

- Land loss along the GIWW is stopped and reversed;
- Exotic invasive woody plants make up less than 5 percent of the canopy cover;
- Suitable, well-spaced cavity nesting sites (natural or artificial) exist in sufficient numbers so that cavity availability does not limit breeding wood ducks and black-bellied whistling-ducks;
- Suitable emergent tree crowns exist to provide nesting sites for bald eagles and ospreys;
- Enough suitable rookery sites exist so that availability does not limit breeding by colonial nesting wading birds;
- Exotic animals, particularly feral hogs, neither impact native wildlife nor degrade habitat to a detectable degree.

Rationale: Forested wetland habitats on Mandalay NWR, though they cover less than 6 percent of the refuge, nevertheless increase habitat diversity and provide important habitat for the resources of concern. Bald eagles, osprey, cavity-nesting waterfowl, and colonial nesting wading birds all require woody vegetation near aquatic habitats for nesting. Protecting these habitats from land loss and exotic species and managing them to provide breeding habitat for the resources of concern will help maintain biological integrity, diversity, and ecological health on the refuge.

Resources of Concern: Waterfowl (particularly resident, cavity-nesting species), raptors, colonial nesting wading birds

CCP Objectives: 1.1, 1.3, 2.2

Adaptive Management Monitoring Elements:

Primary Habitat Response Variables	Probable Assessment Methods
▪ Forest structure ▪ Shoreline location	▪ Periodic inspections ▪ Remote sensing data
Primary Wildlife Response Variables	**Probable Assessment Methods**
▪ Populations, use of artificial cavities, and nesting efficiency of cavity-nesting waterfowl ▪ Presence and productivity of raptor nests ▪ Continued presence of wading bird colonies on refuge	▪ Surveys

V Management Strategies

FRESHWATER MARSH MANAGEMENT STRATEGIES

Maintaining and improving the quantity and quality of freshwater marsh and associated open water areas on Mandalay NWR is the most important management outcome for the refuge. All of the refuge's resources of concern depend on these habitats for at least some part of their life cycles, and the marsh itself is an important part of the landscape of the Barataria-Terrebonne Basin, forming the matrix in which other habitats exist. We will use adaptive management principles to select and implement actions which increase the biological integrity, diversity, and ecological health of the refuge's freshwater marsh ecosystem.

POTENTIAL STRATEGIES

On Mandalay NWR, management and restoration of freshwater marsh will consist of the following types of management actions:

- Invasive exotic plant control;
- Invasive exotic animal control;
- Erosion control;
- Restoration of areas where marsh vegetation has been lost to erosion or nutria grazing.

Options for each of these types of management actions are detailed below.

Invasive exotic plant control

Three exotic weeds appear in open-water areas of freshwater marsh on Mandalay NWR: salvinia, water hyacinth, and Cuban bulrush. Options for control include chemical application, biological control, and mechanical removal. More detail for each species is given below.

Giant salvinia (*Salvinia molesta)* and common salvinia (*S. minima)* are free-floating ferns native to Brazil. Giant salvinia was introduced in the 1990s as an ornamental through the aquarium trade to the southeastern United States, where it has escaped cultivation and poses a serious threat to freshwater resources throughout the southern tier of states from Florida to Texas (U.S. Department of Agriculture 2012). Common salvinia was apparently introduced to Florida early in the 20th Century and has spread westward along the Gulf coast. The circumstances of the introduction are unclear (Jacono et al. 2001). Both of these species form dense mats of vegetation which impede boat traffic, shade out submerged vegetation, and cause anoxic conditions in aquatic habitat.

Control of salvinia with herbicides has been successful. Because of the water-repellent nature of the plant's fronds, the use of proper surfactants is required for efficacy. Herbicides which are labeled and successfully used to control salvinia in the United States include glyphosate, fluridone, and diquat (McFarland, Nelson & Grodowitz 2004). Eradication of salvinia with herbicides is rarely possible, so herbicide applications must be repeated to prevent reestablishment.

A biological control agent has been successfully used to control giant salvinia in the United States and other locations in the tropics and subtropics where it is a pest (Diop 2006). The Curculionid weevil *Cyrtobagous salviniae* feeds on buds and rhizomes of *Salvinia molesta*, causing dramatic

declines in cover which have been shown to persist for several years without reintroduction of the weevil in Texas and Louisiana (Tipping et al. 2008). This weevil is apparently also effective against *S. minima* (Jacono, Davern & Center 2001). *C. salviniae* was released on Mandalay NWR in 2011 and 2012 in cooperation with Louisiana Department of Wildlife and Fisheries and Louisiana State University (Figure 8), and it appears to be surviving and reproducing, although it is too early to evaluate the success of the introduction.

Figure 8. Pond infested with Salvinia molesta showing areas of kill caused by recent release of Cyrtobagous salviniae, Mandalay NWR (Photo Credit: USFWS)

Photo Credit: USFWS

Water hyacinth (*Eichhornia crassipes*) is a floating perennial herb in the monocot family Pontederiaceae. It is native to Brazil and was introduced to the southern United States in 1884 as an ornamental (IFAS 2012). Water hyacinth cover can double every 11-18 days (Coetzee et al. 2009) and is thus capable of covering large bodies of water quickly. It completely changes the ecology of formerly open-water habitat by shading out rooted submersed vegetation and reducing animal diversity (Coetzee et al. 2009). Heavy infestations choke waterways and interfere with boat traffic.

An integrated approach to controlling this weed includes mechanical or hand removal for small infestations, herbicide applications for larger infestations, and biological control measures consisting of three insects imported from the native range of the plant (Charudattan 1986). Two weevils (*Neochetina eichhorniae* and *N. bruchi*) were introduced to the southeastern United States in 1974 and help suppress water hyacinth by burrowing in and feeding on the plant both as adults and larvae. A moth (*Niphograpta albiguttalis*), introduced from Argentina, also contributes to suppressing water hyacinth. The larvae of this insect burrow into the plants and cause necrosis and wilting, killing the plants in some cases (IFAS 2012; Charudattan 1986; Coetzee et al. 2009). However, these biocontrol agents have not been sufficient in and of themselves for achieving the desired level of control of water hyacinth in many areas of the southeastern United States. Herbicides effective against infestations of water hyacinth include 2,4-dichlorophenoxyacetic acid, glyphosate, diquat, and paraquat (Coetzee et al.). Control achieved by herbicides is usually temporary, as propagules usually survive or are readily reintroduced.

Cuban bulrush (*Oxycaryum cubense*) is an exotic weed which can form monospecific or mixed floating mats of vegetation. On Mandalay NWR, this species colonizes infestations of salvinia in shallow open-water areas, contributing to the stability and biomass of floating mats. Herbicides which are effective against Cuban bulrush and labeled for aquatic use include 2,4-D, diquat, glyphosate, and imazapyr (U.S. Army Corps of Engineers 2011). There are no approved biological control agents for this species in the United States.

Invasive exotic animal control

Feral swine (*Sus scrofa*) have been widely introduced into North America and now pose problems for land managers in most areas of the United States. Hogs are prolific and adaptable, able to survive and reproduce in a wide range of habitats and climates. Their omnivorous diet and high reproductive rate combine to make them at once destructive and hard to control. Among their various prey items are the nests of ground-nesting birds and reptiles and young of native mammals such as white-tailed deer (*Odocoileus virginianus*) (Steward et al. 2004).

Control methods in the United States usually consist of some combination of trapping and shooting (Seward et al., 2004). Toxic baits have been used in Australia and other locations (Choquenot et al. 1996), but are problematic because of non-target effects.

Nutria (*Myocastor coypus*) are herbivorous aquatic rodents native to South America which damage marsh habitats in the southern United States by grazing and burrowing. They were introduced into Louisiana in 1938 by E.A. McIlhenny of Avery Island for the purpose of fur farming. A hurricane two years later facilitated their escape, and they soon proliferated all along the Gulf coast (Presnall 1958). Resource impacts from nutria can range from heavily grazed patches to the complete conversion of emergent marsh vegetation to open water through a combination of heavy grazing and burrowing. Vegetation is destroyed, and easily eroded marsh soils are soon lost. Water control structures can be undermined by their burrowing activities (Carter & Leonard 2002). State surveys of nutria damage in Louisiana have documented damage up to 12,000 acres in one year in Terrebonne Parish alone (Marx, Mouton & Linscombe 2004).

As with hogs, use of poisons to control nutria can kill non-target organisms and is not used on Mandalay NWR. Shooting can occur during the day or at night, and can be very effective alone or when combined with trapping. Various styles of traps are used, depending on the potential for non-target captures (LeBlanc 1994).

The following are potential strategies for controlling nutria and swine on the refuge. All control methods discussed are authorized by 50 CFR 31.14.

- Participate in the Louisiana CNCP, and partner with local trappers to reduce nutria and hog populations. On Mandalay NWR, as of 2012, contractor trapping has resulted in extremely low hog populations and significant reduction of nutria effects on marsh vegetation.
- Manage nutria and hog populations through a combination of shooting, trapping, and snaring, using qualified refuge personnel. Continuous monitoring of populations is required to identify trigger points for control actions.
- Contract an intensive nutria control program through USDA or a private contractor, potentially using traps, dogs, GPS tracking systems, and/or guns. This kind of effort can be very expensive (Jojola, Witmer & Nolte 2005).
- Contract an intensive feral hog control program through USDA, using aerial gunning, GPS tracking system, and/or dogs. This type of combined approach has been shown to be effective (McCann & Garcelon 2008). Aerial gunning of hogs is a way to quickly reduce numbers in an area, but it can be expensive (Saunders & Bryant 1987). Effects of disturbance to migratory and nesting waterbirds would need to be evaluated prior to implementation.
- Public hunting for hog removal can have an effect, but generally needs to be used in conjunction with other tools to effectively reduce numbers and keep them low within a given geographical area (Bieber & Ruf 2005). A public hunt strategy, especially for hogs, can have unintended consequences, as it may set up perverse incentives for individuals to attempt to perpetuate the species by selective taking of boars, or illegally releasing animals on the refuge. Hunting of feral hogs is currently permitted on Mandalay NWR.

Erosion control

Ship traffic in the GIWW creates waves which erode away the spoil banks of the waterway. In places where wave action has cut through the spoil bank, fragile marsh soils erode away, creating "blowouts" and converting former marsh to open water. In 2003, a CWPPRA project (Mandalay Bank Protection Demonstration, TE-41) was completed. This project was designed to test the efficacy and cost-effectiveness of a number of different repair structures for stopping erosion and rebuilding marsh. Details of the construction and results of the demonstration project are published on the CWPPRA website (U.S. Geological Survey 2012). A map of the project is presented in Appendix F. In the Operations, Maintenance, and Monitoring Report (dated 2007), no summary comparison of methods was presented, but it appeared that wood fencing with planting of giant cutgrass (*Zizaniopsis miliacea*) and fiberglass sheet piling resulted in significant accretion of sediment behind the structures. A-Jacks also resulted in accretion of material, but tended to sink into the substrate and could lose effectiveness. Concrete revetment mats resulted in further erosion, possibly because they, too, tended to sink after installation. After final evaluation data are available for project TE-41, additional CWPPRA funding could be sought for operational installation of the most successful treatment(s) along all eroding portions of the refuge's GIWW shoreline. However, funding priorities will dictate whether operational shoreline stabilization is conducted.

Marsh restoration

Restoration of marsh vegetation will be the most successful where substrate is stable and the risk of erosion is low. Marsh restoration can be accomplished by a number of different methods. Where adequate sediment is in place, planting of appropriate emergent plant species can be effective. This approach has been used at Bayou Sauvage NWR, as well as many other sites on the Gulf coast.

Areas where sediment has been lost to erosion can be restored by beneficial deposition of dredge material or by dedicated dredge material application. Newly filled areas can be left to revegetate on their own or can be planted. CWPPRA beneficial dredge material deposition projects on Big Branch Marsh NWR have been successfully planted to marsh grasses (CWPPRA project PO-33) (U.S. Geological Survey 2012), and areas filled with sediment from dredging of the Calcasieu Ship Channel have successfully revegetated to *Spartina alterniflora* marsh on Sabine NWR after 3 years without planting. A 20-acre site on Mandalay NWR in the Hanson Unit was filled with dredge material (dedicated dredging) from the GIWW in 2011. Funding for this project, which cost $750,000, was provided by a NAWCA grant. As of February 2012, this site appeared to be mostly vegetated with annual dicots, notably *Ludwigia octovalvis* and *Sesbania punicea*.

Freshwater flotant marsh, dominated by *Panicum hemitomon*, which covers a significant portion of Mandalay NWR, has been successfully restored on an experimental scale on the refuge (Sasser et al. 2010) (U.S. Geological Survey 2012). The authors recommend operational-scale application of their technique on the refuge and other sites where flotant marsh restoration is desired.

MANAGEMENT STRATEGY PRESCRIPTIONS

The following strategies have been selected for managing freshwater marsh on Mandalay NWR:

- To meet Habitat Management Objective 4.1.1, integrated pest management principles will be applied to controlling salvinia, water hyacinth, Cuban bulrush, and Chinese tallow. Releases of *Cyrtobagous salviniae* will continue until the insect is well established on the refuge. Salvinia infestations will be periodically monitored to determine efficacy of this control method and to ascertain whether the insect is successfully established. Approved herbicides will be used as needed to control water hyacinth and Cuban bulrush where they form floating mats and degrade marsh and shallow open water habitat. All herbicides will be approved through the pesticide use proposal process and will follow Integrated Pest Management Policy (569 FW 1). An up-to-date list of approved herbicides is kept on file at the Complex.
- To meet Habitat Management Objectives 4.1.1 and 4.1.2, the following strategies will be used to control nutria and feral hog populations:
    - Monitor populations of feral hogs and nutria on the refuge using established protocols.
    - Continue to partner with area trappers to reduce nutria and feral hog populations.
    - Participate in the State of Louisiana Nutria Control program by actively promoting the program and seeking assistance from area trappers to reduce nutria populations on refuge lands consistent with the state's Nuisance Animal Control Plan.
    - Focused nutria control (i.e., contract trapping, shooting) will be practiced as needed in the event that flotant marsh creation is implemented on an operational basis, as recommended by (Sasser et al. 2010).
- To meet Habitat Management Objectives 4.1.1 and 4.1.2, the following strategy has been selected to control erosion along the GIWW:
    - Seek funding to implement successful bank stabilization practices at operational scale along the GIWW. Where appropriate, marsh restoration strategies, as discussed below, will be coupled with bank stabilization.
- To meet Habitat Management Objective 4.1.2, the following strategies have been selected to restore marsh vegetation on Mandalay NWR:
    - Seek funding to implement beneficial or dedicated dredge deposition projects along the GIWW, focusing on open-water areas behind bank stabilization projects and open ponds where there is a risk of breakthrough to the GIWW.

- Work with partners and volunteers to plant appropriate emergent marsh species in beneficial dredge spoil deposition sites, areas where nutria have denuded marsh vegetation, and areas behind bank stabilization projects where sediment has accumulated and natural revegetation is inadequate.
- Seek funding to implement operational flotant marsh restoration as described by (Sasser et al. 2010), in the event that significant areas of floating marsh are lost due to storm damage, nutria, or other causes.

FORESTED WETLAND MANAGEMENT STRATEGIES

POTENTIAL STRATEGIES

Forested wetlands on Mandalay NWR make up a small but important fraction of the refuge's habitats. Bottomland hardwood forest, which covers approximately 175 acres of the Ridge Canal unit, can in principle be silviculturally manipulated to improve habitat conditions (LMVJV Forest Resource Conservation Working Group 2007). However, the small size and access limitations on Mandalay NWR preclude most active silvicultural management of this habitat. Likewise, baldcypress-tupelo swamp has a very limited extent on the refuge, totaling about 75 acres, all in the Ridge Canal unit. Passive management of this habitat is the only practical alternative. Practices which may be feasible in this unit include invasive plant and animal control, installation and maintenance of artificial cavities for cavity-nesting waterfowl, and regeneration of small areas of hardwoods lost to blowdown, or in areas where invasive plants have been removed.

Invasive exotic plant control

On Mandalay NWR, the major weed of woody habitats is Chinese tallow (*Triadica sebifera*). Chinese tallow can cause major shifts in ecosystem structure and processes, displacing native species and reducing habitat quality (Jubinsky & Anderson 1996). Tallow has replaced coastal prairie vegetation with near-monotypic stands in Texas (Bruce et al. 1995) and Louisiana (Grace et al. 2005). On Mandalay NWR, tallow has infested portions of the Ridge Canal unit and most of the spoil banks.

Options for control of this species include mechanical removal, fire, and herbicides. Biological control of tallow is a possibility for the future.

- No biological control agents have been approved for use in the United States. A leaf-rolling weevil (*Heterapoderopsis bicallosicollis*) and the noctuid moth (*Gadirtha inexacta)* have been evaluated; however, further testing of efficacy under field conditions is required before it is known whether these potential biological control agents have real promise (Wang et al. 2011).
- Mechanical removal has generally been ineffective, as soil disturbance creates opportunities for regeneration (Jubinsky 1993; Thorpe 1996).
- Fire can be an effective tool to reduce the importance of tallowtree where adequate fuels exist; however, as stand density increases, fuels become inadequate to carry fire, and mechanical or chemical treatments must be used in conjunction with fire to control tallowtree (Grace et al. 2005). Prescribed fire is not commonly used in bottomland hardwood habitat, however, and this approach would not be feasible on Mandalay NWR due to lack of adequate fuels and burning conditions, and potential negative effects on desirable vegetation.

- Chemical treatment is currently the most effective large-scale strategy for controlling tallowtree (Jubinsky & Anderson 1996). Herbicides which can be used include 2,4-D+2,4-DP, clopyralid (Escort), imazapyr (Arsenal), fosamine (Krenite), hexazinone (Velpar), and triclopyr (Garlon, Pathfinder) (Maddox et al. n.d.).

Artificial nesting cavities

Wood duck boxes are a frequently used management tool for supplementing natural cavities in wood duck habitat. Success of an artificial cavity program for ducks depends on proper placement of the boxes, proper design (including adequate predator guards), and timely and sufficient maintenance. Pragmatic requirements of maintenance may mean that boxes are not placed in the most ideal location from a habitat standpoint. However, placement considerations can mean the difference between success and failure of a program. In particular, nests should be placed in secluded locations near good brood habitat and not be visible from each other. Having too many boxes can be counterproductive, leading to overpopulation, density strife, and reduced nesting efficiency (Haramis & Thompson 1985). Recommended use of duck boxes is as a supplement to natural cavities (Dugger & Fredrickson 2007). Thus, a properly designed artificial cavity program will include a monitoring element which yields data on the density and use of natural cavities in the habitat. Less is known about use of artificial cavities by black-bellied whistling-ducks than by wood ducks; however, it is reasonable to assume that some degree of competition for cavities occurs between the two species.

On Mandalay NWR, availability of natural cavities in the Ridge Canal unit is poorly known, but appears to be high. Duck boxes have received very little use in the past few years. The refuge currently has 20 duck boxes, but only 1 or 2 are used by wood ducks or black-bellied whistling-ducks each year.

Hardwood regeneration

In passively managed hardwood forests, regeneration is usually allowed to proceed with minimal intervention, except perhaps for control of exotic plants like Chinese tallow or of animals like feral hogs. When natural seeding or coppice regeneration is feasible, these are almost always the preferred alternative because of their low cost. When natural regeneration fails or results in undesirable species mixes, artificial regeneration (direct-seeding or planted seedlings) can be used to supplement or replace naturally regenerated stems. In such cases, site preparation will probably be required.

MANAGEMENT STRATEGY PRESCRIPTIONS

The following strategies will be used to manage forested wetland habitat to achieve the objectives listed above:

- Chinese tallow will be controlled on bottomland hardwood sites in the Ridge Canal unit by application of Garlon 4 or equivalent as a basal spray in diesel, or by other herbicide treatment as approved. The unit will be assessed at least every 3 years, and treatment will be prioritized by density and age of tallow trees (i.e., seed-bearing populations will receive higher priority). Infestations which are interfering with natural regeneration in blowdowns and other disturbed areas will also receive high priority for treatment. Tallow infestations on spoil banks will be treated as funding and resources are available, but are a lower priority than those in natural habitats. All herbicides will be approved through the pesticide use proposal process and will follow Integrated Pest Management Policy (569 FW 1). An up-to-date list of approved herbicides is kept on file at the Complex.

- The refuge will evaluate the need for an artificial nest cavity program for waterfowl. Low levels of use in past years, coupled with a healthy population of wood ducks on the refuge, indicate that natural cavities are not limiting wood duck breeding. Periodic monitoring of wood ducks will be used to support decisions on increasing, decreasing, activating, or deactivating the program in the future. Funding constraints will be considered when deciding where and how many boxes will be placed.
- In the Ridge Canal unit, areas of blowdown and other disturbance will be allowed to naturally regenerate. As funding and resources are available, the refuge will supplement natural regeneration with seedlings of hard mast-producing species (water oak, Nuttall oak, water hickory) when these species are lacking due to absence of seed sources on otherwise compatible sites. Management will also consider reforesting areas of spoil bank or other suitable areas that have been cleared for oil and gas operations or other uses and need restoration.
- Currently human disturbance of the eagle nest has not been a problem since the area around the nest is relatively inaccessible. Refuge staff will monitor the situation for any changes, and will implement appropriate buffer zones if necessary.

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Appendix B: Authors and Contributors

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Alex Michalek, *Forester*

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Appendix C. Refuge Vertebrate Biota

Species of concern and/or significance for management purposes occurring on Mandalay NWR are listed below. For a complete list of birds found on the refuge, contact the Complex for a bird list.

BIRDS	
Bald Eagle	*Haliaeetus leucocephalus*
Eastern Brown Pelican	*Pelecanus occidentalis carolinensis*
Wood Duck	*Aix sponsa*
Gadwall	*Anas strepera*
American Wigeon	*Anas americana*
Mallard	*Anas platyrhynchos*
Mottled Duck	*Anas fulvigula*
Blue-winged Teal	*Anas discors*
Northern Shoveler	*Anas clypeata*
Northern Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Greater Scaup	*Aythya marila*
Lesser Scaup	*Aythya affinis*
Common Goldeneye	*Bucephala clangula*
Bufflehead	*Bucephala albeola*
Hooded Merganser	*Lophodytes cucullatus*
Red-breasted Merganser	*Mergus serrator*
Ruddy Duck	*Oxyura jamaicensis*
Black-bellied whistling Duck	*Dendrocygna autumnalis*
Osprey	*Pandion haliaetus*
King Rail	*Rallus elegans*
Clapper Rail	*Rallus longirostris*
Purple Gallinule	*Porphyrio martinica*
Common Gallinule	*Gallinula galeata*
Greater Yellowlegs	*Tringa melanoleuca*
Lesser Yellowlegs	*Tringa flavipes*
Great Blue Heron	*Ardea herodias*
Great Egret	*Ardea alba*
Green Heron	*Butorides virescens*
Tricolored Heron	*Egretta tricolor*
Black-crowned Night Heron	*Nycticorax nycticorax*

Yellow-crowned Night-Heron	*Nyctanassa violacea*
Roseate Spoonbill	*Platalea ajaja*
American Avocet	*Recurvirostra americana*
Black-necked Stilt	*Himantopus mexicanus*
Pied-billed Grebe	*Podilymbus podiceps*
American Bittern	*Botaurus lentiginosus*
Least Bittern	*Ixobrychus exilis*
Little Blue Heron	*Egretta caerulea*
White Ibis	*Eudocimus albus*
Wood Stork	*Mycteria americana*
Northern Harrier	*Circus cyaneus*
Yellow-billed Cuckoo	*Coccyzus americanus*
Acadian Flycatcher	*Empidonax virescens*
Yellow-throated Vireo	*Vireo flavifrons*
Prothonotary Warbler	*Protonotaria citrea*
Painted Bunting	*Passerina ciris*

MAMMALS

White-tailed Deer	*Odocoileus virginianus*
Nutria	*Myocastor coypus*
Feral Hog	*Sus scrofa*

REPTILES AND AMPHIBIANS

American Alligator	*Alligator mississippiensis*
Alligator Snapping Turtle	*Macrochelys temminckii*

FISH

Alligator Gar	*Atractosteus spatula*

Appendix D: Listed, Candidate, and Recovered Species Known to Occur on Mandalay NWR

Group	Name	Population	Status
Birds	Bald Eagle (*Haliaeetus leucocephalus*)	U.S.A. conterminous states	Recovery

Appendix E: Soils

Table E1. Names, taxonomic classification, and management information for soil mapping units on Mandalay NWR

All information taken verbatim from (Natural Resources Conservation Service 2012)

Map Unit	Series Name	Landform	Taxonomic Classification	Management Information
AEA	Allemands muck, very frequently flooded	Marshes	Clayey, smectitic, euic, hyperthermic Terric Haplosaprists	The Allemands component makes up 85 percent of the map unit. Slopes are 0 to 0 percent. This component is on marshes on delta plains. The parent material consists of herbaceous organic material over fluid clayey alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is very poorly drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is very high. Shrink-swell potential is low. This soil is very frequently flooded. It is frequently ponded. A seasonal zone of water saturation is at 0 inches throughout the year. Organic matter content in the surface horizon is about 58 percent. This component is in the R151XY007LA Fresh Organic Marsh ecological site. Non-irrigated land capability classification is 8w. This soil meets hydric criteria. The soil has a slightly sodic horizon within 30 inches of the soil surface.
ATB	Aquents, dredged, 1 to 5 percent slopes, occasionally flooded	Marshes, backswamps	Nonacid, hyperthermic Aquents	The Aquents component makes up 85 percent of the map unit. Slopes are 1 to 5 percent. This component is on marshes on delta plains. The parent material consists of alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is very poorly drained. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is occasionally flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. This soil meets hydric criteria.

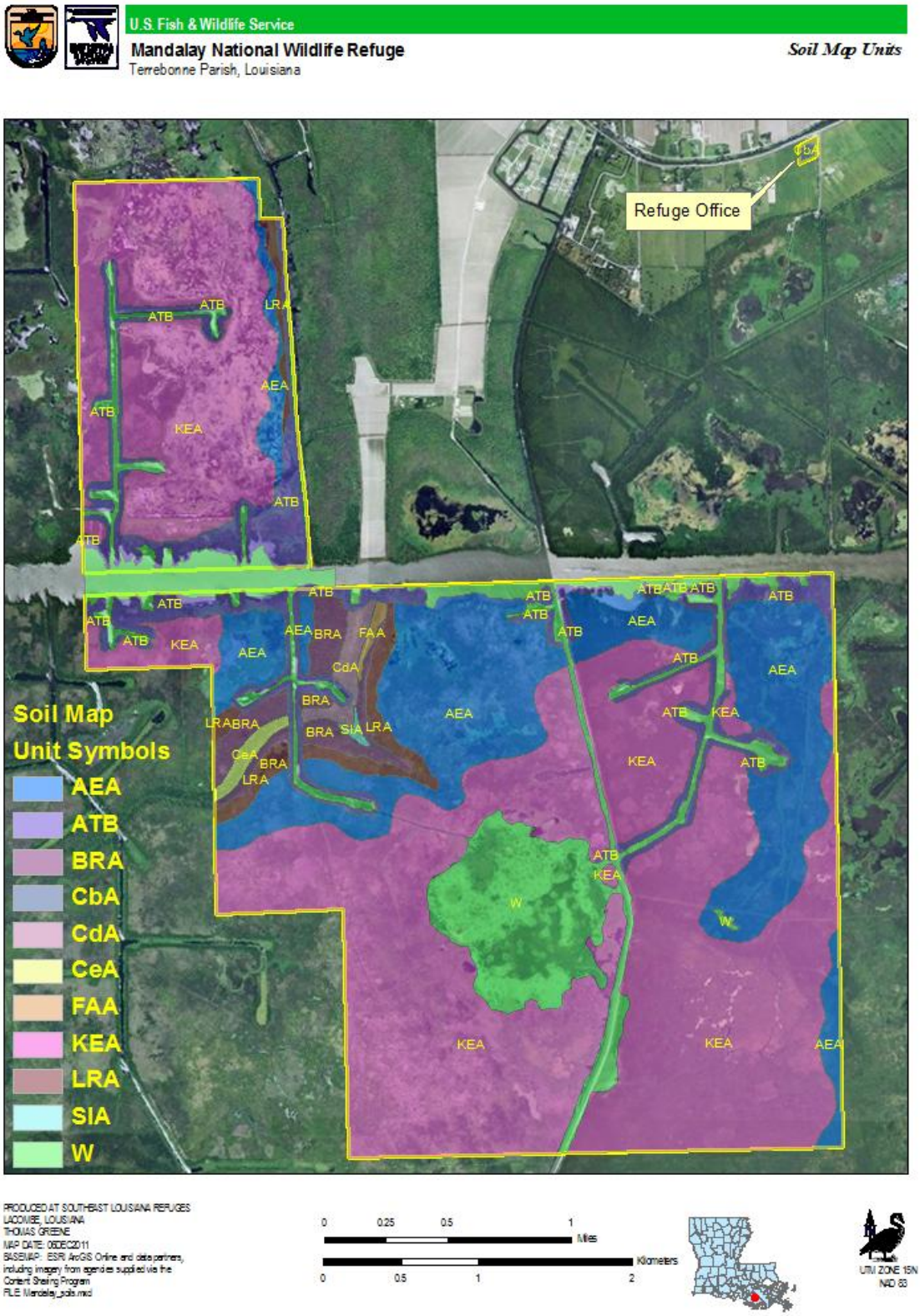
Map Unit	Series Name	Landform	Taxonomic Classification	Management Information
BRA	Barbary muck, frequently flooded	Swamps	Very-fine, smectitic, nonacid, hyperthermic Typic Hydraquents	The Barbary component makes up 85 percent of the map unit. Slopes are 0 to 0 percent. This component is on swamps on delta plains. The parent material consists of fluid clayey alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is very poorly drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is very high. Shrink-swell potential is low. This soil is frequently flooded. It is frequently ponded. A seasonal zone of water saturation is at 0 inches throughout the year. Organic matter content in the surface horizon is about 50 percent. Non-irrigated land capability classification is 8w. This soil meets hydric criteria.
CbA	Cancienne silt loam, 0 to 1 percent slopes	Natural Levees	Fine-silty, mixed, superactive, nonacid, hyperthermic Fluvaquentic Epiaquepts	The Cancienne component makes up 85 percent of the map unit. Slopes are 0 to 1 percent. This component is on natural levees on delta plains. The parent material consists of loamy alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is somewhat poorly drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. A seasonal zone of water saturation is at 33 inches during January, February, March, April, and December. Organic matter content in the surface horizon is about 2 percent. Non-irrigated land capability classification is 3w. This soil does not meet hydric criteria.

Map Unit	Series Name	Landform	Taxonomic Classification	Management Information
CdA	Cancienne silty clay loam, 0 to 1 percent slopes	Natural Levees	Fine-silty, mixed, superactive, nonacid, hyperthermic Fluvaquentic Epiaquepts	The Cancienne component makes up 85 percent of the map unit. Slopes are 0 to 1 percent. This component is on natural levees on delta plains. The parent material consists of loamy alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is somewhat poorly drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. A seasonal zone of water saturation is at 33 inches during January, February, March, April, and December. Organic matter content in the surface horizon is about 2 percent. Non-irrigated land capability classification is 2w. This soil does not meet hydric criteria.
CeA	Cancienne silty clay loam, 0 to 1 percent slopes, occasionally flooded	Natural levees	Fine-silty, mixed, superactive, nonacid, hyperthermic Fluvaquentic Epiaquepts	The Cancienne component makes up 85 percent of the map unit. Slopes are 0 to 1 percent. This component is on natural levees on delta plains. The parent material consists of loamy alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is somewhat poorly drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is moderate. This soil is occasionally flooded. It is not ponded. A seasonal zone of water saturation is at 33 inches during January, February, March, April, and December. Organic matter content in the surface horizon is about 2 percent. Non-irrigated land capability classification is 3w. This soil does not meet hydric criteria.

Map Unit	Series Name	Landform	Taxonomic Classification	Management Information
FAA	Fausse clay, frequently flooded	Backswamps	Very-fine, smectitic, nonacid, hyperthermic Vertic Endoaquepts	The Fausse series consists of level, very poorly drained, very slowly permeable soils. In a representative profile the surface layer is very dark brown muck and dark gray clay; the subsoil is gray clay mottled with brown. These soils formed in thick beds of Mississippi River clayey alluvium. They occur at low local elevations.
KEA	Kenner muck, very frequently flooded	Marshes	Euic, hyperthermic Fluvaquentic Haplosaprists	This soil is level, very poorly drained, and fluid. It is an organic soil that is in freshwater marshes. The soil is fluid muck throughout, except for a thin layer of fluid clay in the underlying material. This soil has low strength and poor trafficability. The total subsidence potential is very high.
LRA	Larose muck, very frequently flooded	Marshes	Very-fine, smectitic, nonacid, hyperthermic Typic Hydraquents	The Larose component makes up 85 percent of the map unit. Slopes are 0 to 0 percent. This component is on marshes on delta plains. The parent material consists of thin herbaceous organic material over fluid clayey alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is very poorly drained. Water movement in the most restrictive layer is very low. Available water to a depth of 60 inches is high. Shrink-swell potential is low. This soil is very frequently flooded. It is frequently ponded. A seasonal zone of water saturation is at 0 inches throughout the year. Organic matter content in the surface horizon is about 58 percent. This component is in the R151XY008LA Fresh Fluid Marsh ecological site. Non-irrigated land capability classification is 8w. This soil meets hydric criteria. The soil has a slightly sodic horizon within 30 inches of the soil surface.

Map Unit	Series Name	Landform	Taxonomic Classification	Management Information
SIA	Schriever clay, frequently flooded	Backswamps	Very-fine, smectitic, hyperthermic Chromic Epiaquerts	This nearly level, poorly drained, soil is on broad flats on the alluvial plain. It is clayey throughout. Natural fertility is medium or high. Runoff is slow or very slow. Water and air move very slowly through the soil. The shrink-swell potential is high or very high. A seasonal high water table is within 2 feet of the soil surface during December through April. Flooding is rare, but it can occur during unusually wet periods. Slopes are less than 1 percent. These are wet, clayey soils with a high potential for productivity. Equipment limitations and seedling mortality are severe. This is due primarily to excess water. Silvicultural operations should be restricted to dry weather periods. Only tree species adapted to wet clay soils should be planted. Plant more seedlings than the recommended rate on these soils to ensure a stand. Site index for green ash is 80, cottonwood 100, and oaks and sweetgum 90.
W	Water			

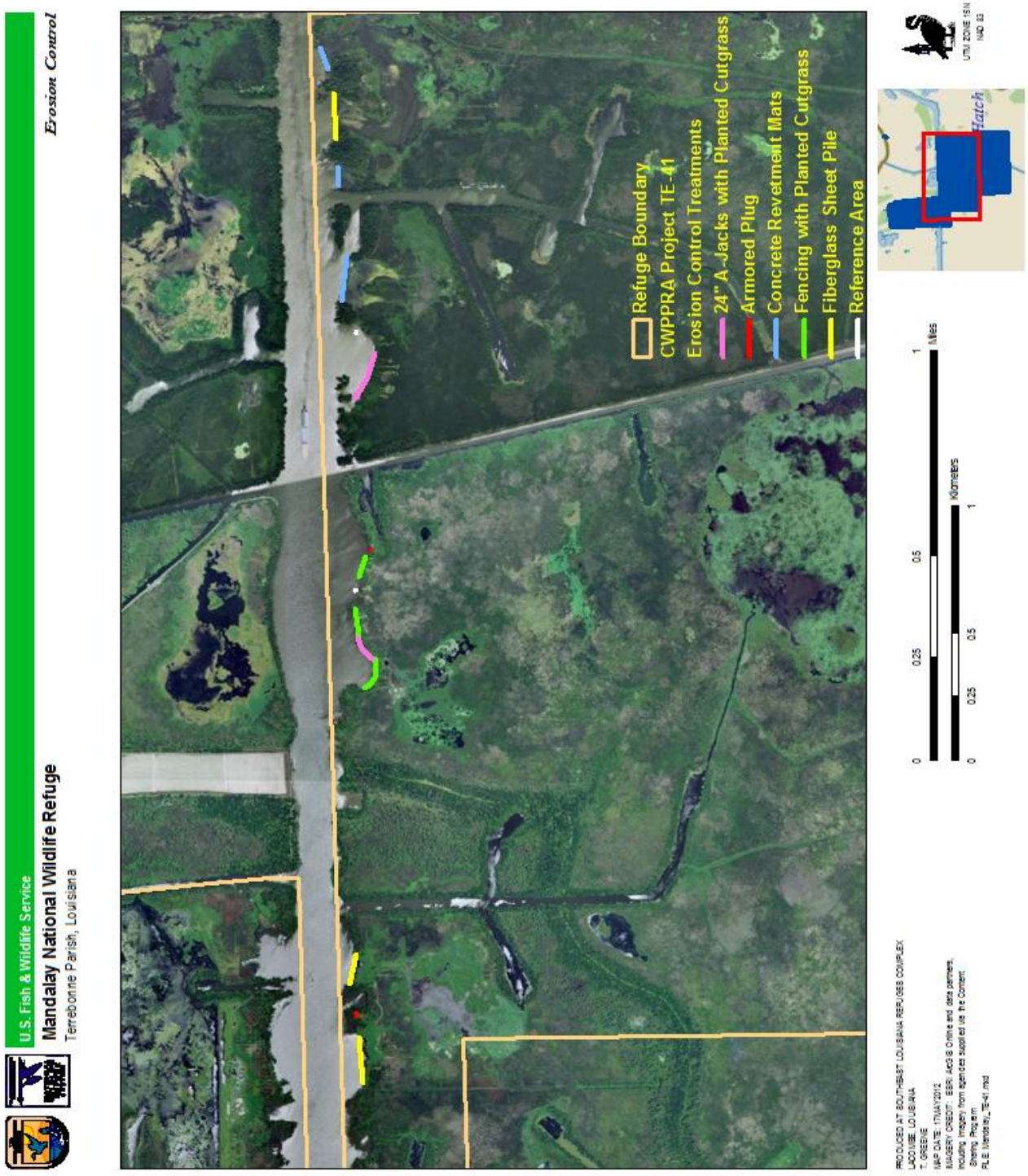
Figure E1. Locations of soil mapping units on Mandalay NWR



source: (Natural Resources Conservation Service 2012). Descriptions for map units are provided in Table E1.

Appendix F. CWPPRA Project Te-41

Figure F1. Locations of erosion control structures installed during 2003 by CWPPRA Project TE-41 along the bank of the GIWW on Mandalay NWR



Appendix G. Environmental Action Statement

U.S. FISH AND WILDLIFE SERVICE

ENVIRONMENTAL ACTION STATEMENT FOR CATEGORICAL EXCLUSION

Within the spirit and intent of the Council on Environmental Quality's regulations for implementing the National Environmental Policy Act (NEPA), and other statutes, orders, and policies that protect fish and wildlife resources, I have established the following administrative record and determined that the following proposed action is categorically excluded from NEPA documentation requirements consistent with 40 CFR 1508.4, 516 DM 2.3A, 516 DM 2 Appendix 1, and 516 DM 6 Appendix 1.4.

Proposed Action and Alternatives. The proposed action is the approval and implementation of the Habitat Management Plan (HMP) for Mandalay National Wildlife Refuge (NWR). This HMP is a step-down management plan which provides the refuge manager with specific guidance for implementing goals, objectives, and strategies identified in the Mandalay NWR Comprehensive Conservation Plan (CCP) (2009a).

The CCP action was the preferred alternative among three alternatives considered in the Environmental Assessment (EA) (USFWS 2009b). Implementing the preferred alternative is resulting in the restoration and improvement of resources needed for wildlife and habitat management, while providing opportunities for a variety of additional compatible wildlife-dependent recreation, education, and interpretive activities. This alternative allows the refuge to provide law enforcement protection that adequately meets the demands of an urban environment (USFWS 2009a).

The CCP has defined goals, objectives, and strategies to achieve the stated action. The actions further detailed in this HMP have been identified, addressed, and authorized by the Mandalay NWR CCP and accompanying EA (USFWS 2009b). These include:

- To meet Habitat Management Objective 4.1.1, integrated pest management principles will be applied to controlling salvinia, water hyacinth, Cuban bulrush, and Chinese tallow. Releases of *Cyrtobagous salviniae* will continue until the insect is well-established on the refuge. Salvinia infestations will be periodically monitored to determine efficacy of this control method and to ascertain whether the insect is successfully established. Approved herbicides will be used as needed to control water hyacinth and Cuban bulrush where they form floating mats and degrade marsh and shallow open water habitat. All herbicides will be approved through the pesticide use proposal process and will follow Integrated Pest Management Policy (569 FW 1). An up-to-date list of approved herbicides is kept on file at the Complex.
- To meet Habitat Management Objectives 4.1.1 and 4.1.2, the following strategies will be used to control nutria and feral hog populations:
    - Conduct yearly evaluations of nutria and feral hog populations on refuge lands, using established monitoring protocols.
    - Continue to partner with area trappers to reduce nutria and feral hog populations.
    - Participate in the State of Louisiana Nutria Animal Control Plan by actively promoting the program and seeking assistance from area trappers to reduce nutria populations on refuge lands consistent with the state's plan.

    - Focused nutria control (i.e., contract trapping, shooting) will be practiced as needed in the event that flotant marsh creation is implemented on an operational basis, as recommended by (Sasser et al. 2010).
- To meet Habitat Management Objectives 4.1.1 and 4.1.2, the following strategy has been selected to control erosion along the GIWW:
    - Seek funding to implement successful bank stabilization practices at operational scale along the GIWW. Where appropriate, the marsh restoration strategies discussed below will be coupled with bank stabilization.
- To meet Habitat Management Objective 4.1.2, the following strategies have been selected to restore marsh vegetation on Mandalay NWR:
    - Seek funding to implement beneficial or dedicated dredge deposition projects along the GIWW, focusing on open-water areas behind bank stabilization projects and open ponds where there is a risk of breakthrough to the GIWW.
    - Work with partners and volunteers to plant appropriate emergent marsh species in beneficial dredge spoil deposition sites, areas where nutria have denuded marsh vegetation, and areas behind bank stabilization projects where sediment has accumulated and natural revegetation is inadequate.
    - In the event that significant areas of floating marsh are lost to storm damage, nutria, or other causes, seek funding to implement operational flotant marsh restoration as described by (Sasser et al. 2010).
- Control Chinese tallow led on bottomland hardwood sites in the Ridge Canal unit by application of Garlon 4 or equivalent as a basal spray in diesel, or by other herbicide treatment as approved. The unit will be assessed at least every 3 years, and treatment will be prioritized by density and age of tallow trees (i.e., seed-bearing populations will receive higher priority). Infestations which are interfering with natural regeneration in blowdowns and other disturbed areas will also receive high priority for treatment. Tallow infestations on spoil banks will be treated as funding and resources are available, but are a lower priority than those in natural habitats. All herbicides will be approved through the pesticide use proposal process and will follow Integrated Pest Management Policy (569 FW 1). An up-to-date list of approved herbicides is kept on file at the Complex.
- Evaluate the need for an artificial nest cavity program for waterfowl. Low levels of use in past years, coupled with a healthy population of wood ducks on the refuge, indicate that natural cavities are not limiting wood duck breeding. Periodic monitoring of wood ducks will be used to support decisions on increasing, decreasing, activating, or deactivating the program in the future. Funding constraints will be considered when deciding where and how many boxes will be placed.
- In the Ridge Canal unit, areas of blowdown and other disturbance will be allowed to naturally regenerate. As funding and resources are available, the refuge will supplement natural regeneration with seedlings of hard mast-producing species (e.g., water oak, Nuttall oak, water hickory) when these species are lacking due to absence of seed sources on otherwise compatible sites. Management will also consider reforesting areas of spoil bank or other suitable areas that have been cleared for oil and gas operations or other uses and need restoration.
- Currently human disturbance of the eagle nest has not been a problem since the area around the nest is relatively inaccessible. The staff will monitor the situation for any changes, and will implement appropriate buffer zones if necessary.

Categorical Exclusion(s). Categorical Exclusion Department Manual 516 DM 6, Appendix 1, Section 1.4 B (10), which states "the issuance of new or revised site, unit, or activity-specific management plans for public use, land use, or other management activities when only minor changes are planned. Examples could include an amended public use plan or fire management plan," is applicable to implementation to the proposed action.

Consistent with Categorical Exclusion (516 DM 6, Appendix 1, Section 1.4 B (10)), the HMP is a step-down management plan which provides guidance for implementation of the general goals, objectives, and strategies established in the CCP, serving to further refine those components of the CPP specific to habitat management. This HMP does not trigger an Exception to the Categorical Exclusions listed in 516 DM 2, Appendix 2.

Minor changes or refinements to the CCP in this activity-specific management plan include:

- Habitat management objectives are further refined by providing numerical parameter values that more clearly define the originating objective statement.
- Habitat management objectives are restated so as to combine appropriate objectives or to split complicated objectives for improved clarity in the context of the HMP.
- Specific habitat management guidance, strategies, and implementation schedules to meet the CCP goals and objectives are included (e.g., location, timing, frequency, and intensity of application).
- All details are consistent with the CCP and serve to provide the further detail necessary to guide the refuge in application of the intended strategies for the purpose of meeting the habitat objectives.

Permits/Approvals

Endangered Species Act, Intra-Service Section 7 Consultation was not conducted during the CCP process for Mandalay NWR. No listed species nor critical habitat for any listed species were found to be on Mandalay NWR.

Public Involvement/Interagency Coordination

Formal public involvement began with an open house held in April 2007 for the general public to give suggestions and comments regarding the future of the refuge. Announcements giving the location, date, and time for the scoping meeting appeared in local newspapers and were furnished to local residents. The public meeting for Mandalay NWR was held in Houma. Approximately 7 people attended the open discussion of the CCP process to learn about future management plans for Mandalay NWR. After orienting attendees to the CCP process, they could move freely among the following discussion areas: public programs and visitor facilities, wildlife and habitat management, and refuge administration. Each area offered information and a chance to make written and oral statements (Appendix D). Also, comment cards were available, which could be mailed to the refuge. Approximately 11 comments and questions were recorded for the Mandalay NWR meeting. Input obtained from the scoping meetings was used to develop the Draft CCP. No major conflicts were declared in the comments received from the public (U.S. Fish and Wildlife Service 2009).

Supporting Documents

Supporting documents for this determination include relevant office file material and the following key references:

Mandalay NWR Final Comprehensive Conservation Plan (USFWS 2009b; on file at the Southeast Louisiana National Wildlife Refuge Complex Headquarters in Lacombe, Louisiana)

Ken Litzenberger — 12/3/12

Project Leader — date

Richard Warner — 03/24/2013

Regional Refuge NEPA Coordinator — date

U.S. Fish and Wildlife Service
Mandalay National Wildlife Refuge

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